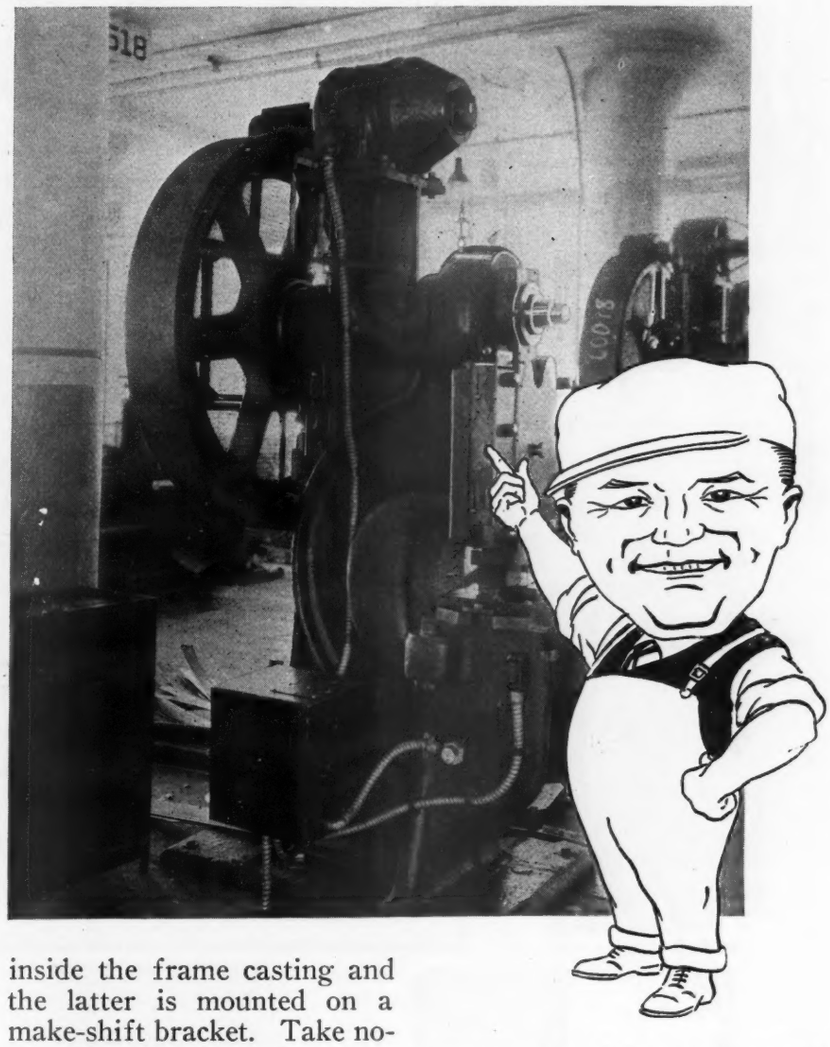
ELECTRICAL REVIEW
AND
INDUSTRIAL ENGINEER

Volume 80 Chicago, June, 1922 *Number 6*

What Suggestions Can You Offer

As Improvements on This Installation?



ON this page in the April issue I called attention to a motor installation in a textile mill that any electrical man might be proud of. Perhaps I should have said "he might be jealous of" for in response to my invitation to send in photos of good installations a number have been received from textile mills which certainly might be labeled just as good as the one I picked on to start this discussion of good and bad features in (1) motor mounting, (2) wiring and (3) control arrangement.

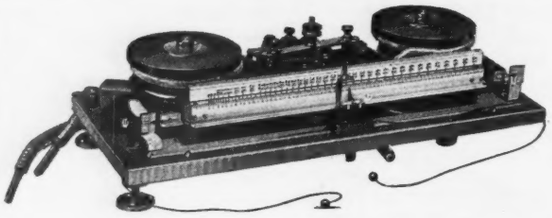
But in this case I have selected a photograph of a motor drive in a large machinery manufacturing plant which might be rated high for item (1) but a little down the scale for items (2) and (3). It is rather interesting to note that considerable attention was paid in the construction of this machine to a suitable foundation for the motor, but little, if any, such attention to the wiring and the mounting of the control cabinet. The former is sort of stuck on the outside instead of being provided for inside the frame casting and the latter is mounted on a make-shift bracket. Take notice, however, that this is an all-conduit job and that this conduit is attached to the motor through a suitable fitting that is made for that particular purpose.

All in all this is a good installation if you overlook the fact that the provision for the electrical part of this machine was something of an afterthought of the maker. It is perhaps a better example of the need for considering the motor, its wiring and control just as essential a part of the completed machine as the driving gear or the shaft on which it rotates. We electrical men need to do a whole lot of thinking along this line for the machine builder. If you have done some of this already, let's hear about it.

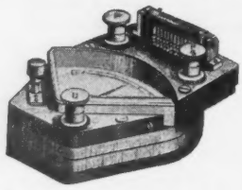
Practical Pete

Changes in Indicating Meters

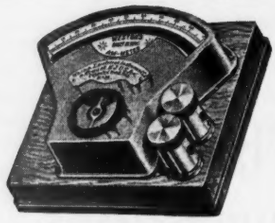
From 1819 to the Present Date



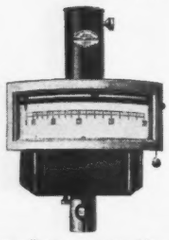
1880 KELVIN AMPERE BALANCE



1881-AYRTON AND PERRY AMMETER



1888-WESTON AMMETER



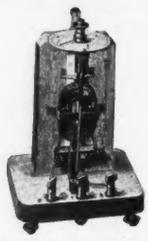
1888-KELVIN ELECTROSTATIC VOLTMETER

IN 1819 when Oersted noticed that a magnetic needle tended to set itself at right angles to an electric current, he discovered the principle of the electric meter. From this discovery developed the galvanometer. Weber, in 1843 first applied Ampere's principle of attraction between two coils carrying current, which resulted in his electro-dynamometer. These two types were highly developed through the efforts of Lord Kelvin, Siemens, and others. Such instruments, however, were not "direct-reading."

The first meters which could be read directly were made by Deprez about 1880. They were developed in a very practical form by Ayrton and Perry in 1881. This type had a magnetic needle, a fixed permanent magnet and a fixed coil. The terms "ammeter" and "voltmeter" were invented by these two men. Weston developed a line of direct-reading meters in 1888. These had a fixed permanent magnet and a moving coil. About the same year, 1888, meters were first employed for measuring alternating currents. In 1889 James W. Queen brought out a magnetic-vane instrument. This type has a fixed coil and a moving vane of soft iron. The magnetic-vane and moving-coil types are in wide use today. Electrostatic voltmeters were developed about 1885 by Kelvin. A hot-wire meter was made by Siemens in 1879 and later Cardew's hot-wire meter was widely used. In 1890 a direct-reading wattmeter was developed by Weston. As early as 1886 Elihu Thomson had constructed a recording meter which left a curve of pin pricks on a chart. The Walker graphic meter, made in 1890, recorded on a strip of photographic paper. In 1893 the Bristol curve-drawing meters were developed. Wright invented a meter in 1896 for measuring maximum demand in amperes. The first successful meter for indicating kilowatt demand was made in 1912. The kilovolt-ampere meter is a recent development.

1889-QUEEN MAGNETIC-VANE AMMETER

1890 WALKER AMMETER



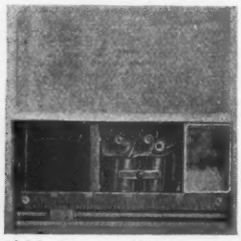
1890-SIEMENS DYNAMOMETER

1886-WIRT VOLTMETER

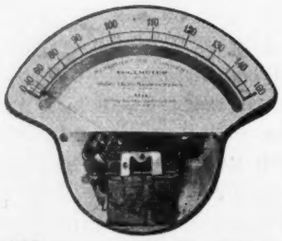
1893 BRISTOL RECORDING VOLTMETER

CARDEW HOT-WIRE VOLTMETER

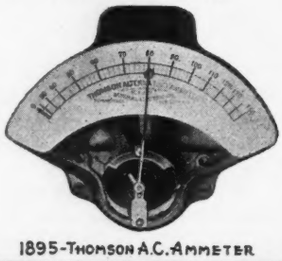
1886-EDISON VOLTAGE INDICATOR



1890-HOWELL VOLTMETER

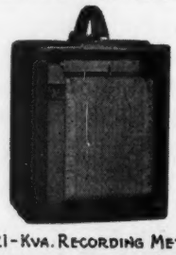


1893-STANLEY A.C. VOLTMETER



1895-THOMSON A.C. AMMETER

1912-MAXIMUM-DEMAND INDICATOR



1921-KVA. RECORDING METER

CONTINUOUS and satisfactory operation of electric motors and other equipment in mills and factories where dust and dirt results from machine operations, requires that the bearings receive careful and skilled attention. In this article Mr. Gear presents some bearing information and shop kinks in maintaining them, that are the result of many years of experience in the operation and maintenance of electrical and mechanical equipment in various industries. The practices described are being successfully applied to an installation of 300 motors, many of which are operating under very adverse conditions.

Here Are

Some Pointers on Bearings

That Will Help to Prevent Failure of Motor Service

By A. L. GEAR

Chief Electrician, Gary Screw and Bolt Company

In order to avoid injuring the motor bearing by pounding, the workman is forcing it into place by screwing up the nut on a long threaded bolt which passes through the bearing.

BEARINGS of an electric motor, generator or other machine perform the important function of supporting a moving part and keeping it in the proper alignment with regard to other moving or stationary parts. From the nature of this service, bearings are subject to so much wear that their life is ordinarily only a small fraction of the life of the machine as a whole. The maintenance and repair of bearings is therefore worthy of careful attention and study.

Motor bearings in use today can be classified as sleeve, roller and ball bearing. The sleeve bearing may be designated for convenience as a broad line contact bearing, for eventually the shaft will wear down to a snug fit and the bearing cover more or less than one-half of the shaft circumference before it is renewed. The roller bearing may be classed as a line contact bearing and will maintain the line contact until practically worn out. The ball bearing may be regarded as a point contact or, if preferred, multiple-point contact, as each ball has two points of contact, one upon the inner race and one upon the outer race. The sleeve bearing is, however, the most widely employed, although roller and ball bearings are coming into more extensive use owing to the higher bearing efficiency obtained. This means less waste of power and permits smaller and lighter machines, especially in electrical designs, to be built. In addition, less operating attention is required and less lubrication is needed which gives on motors and generators a winding which is cleaner and less liable to ground from the presence of oil and dust. Lubricating oil of itself may be a fair insulator, but in combination with dust and grit it is very likely in time to form a ground from the winding to the frame of the machine. Again, if the windings are only moist with oil it forms a sticky surface to which all particles drawn through the machine by the fan may adhere and thus cause partial if not complete stoppage of the air ducts.

The length of motor and generator sleeve bearings is usually two and one-half to four times the diameter of the bore. Thus a bearing for an armature shaft two inches in diameter may be from five inches to eight inches in length. The length varies with the area required to give the desired pressure per square inch. At times a considerable por-

tion of the bearing may be placed under the back or pulley end of the armature winding. In Westinghouse type K4 and K6 motors the bearings extend under the winding and also under the commutator, thereby shortening the motor to a length suitable for crane work.

Bearing Linings Are Made of Soft Metal in Order to Reduce Wear on the Shaft

The sleeve bearing is usually composed of an outer shell of cast-iron, steel or brass with a lining of a comparatively soft metal into which are cut suitable grooves or oilways for carrying oil the length of the bearing parallel with the shaft. Cast-iron and steel bearing shells are lined to reduce friction, to substitute a metal easily worked and renewed, and to place in contact with the revolving armature or other shaft a metal that is softer and will wear more easily. The shaft will then have to be turned down or replaced only at long intervals, while the bearing may be renewed a number of times.

Often a good deal of work is involved in replacing an armature shaft, particularly if the commutator is keyed directly upon the shaft rather than upon a spider attached to the armature core laminations. In such a case all of the commutator connections must be unsoldered and the commutator removed from the shaft and wound core, after which the core with the winding is removed from the shaft. If the commutator is shrunk or keyed to an armature spider, the commutator, armature core, spider and all are removed in one piece. Therefore, it may readily be seen that it is cheaper and easier to renew the bearings than the armature shaft.

A number of different alloys are suitable for use as linings for bearings. One of the alloys which has been extensively used for many years is known as babbitt, from the name of its inventor. Babbitt metals vary considerably in composition, but are essentially tin-base alloys containing smaller amounts of antimony, copper, lead or zinc. Soft genuine babbitt metal contains approximately 89 per cent tin, 7 per cent antimony and 4 per cent copper. Hard genuine babbitt metal contains, roughly, 83 per cent tin, 8.5 per cent antimony and 8.5 per cent copper. For the bearings of

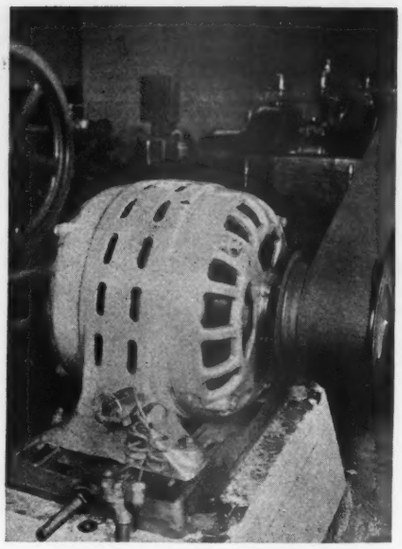


Fig. 1—Ball bearings on this motor reduce the amount of attention required.
This is a 25-hp. Fairbanks-Morse motor driving a cold-heading machine. After being packed with grease these bearings will run for months without any attention. Note the narrowness of the bearing as compared with some of the sleeve bearings illustrated elsewhere.

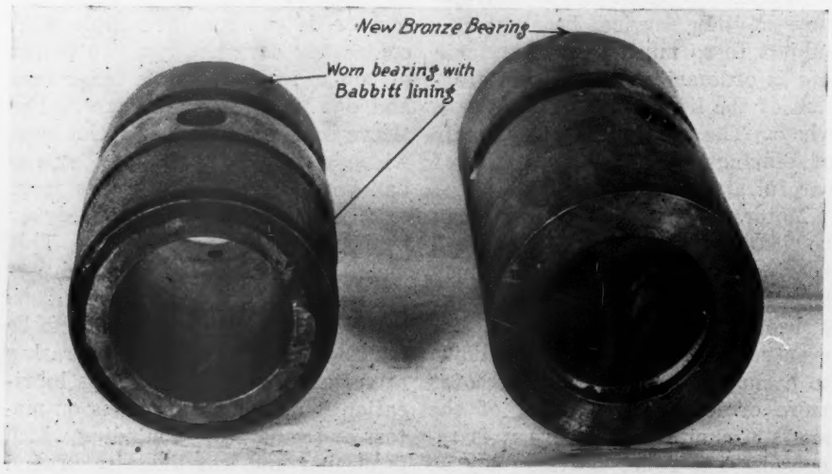
motors of average speed and horsepower, I have found that Paul S. Reeves A1, Westinghouse No. 14 and a babbitt composed of approximately 74 per cent tin, 5 per cent copper, 8 per cent lead and 13 per cent antimony give good results.

In passing it may be said that instead of throwing away brass or bronze bearings after they have become worn down in service, it is our practice to rebore them in a lathe and then babbitt them as would be done in the case of a cast-iron or steel shell, after which they may be bored to fit the shaft. Fig. 2 shows a new bronze bearing and one which has been babbitted as described.

Bearing shells may also be of a two-piece pattern as shown in Fig. 3. This shell when babbitted is bolted together and bored to the proper diameter for a shaft fit; .005 in. to .010 in. oversize is allowable in practice when boring babbitted bearings. Bronze bearings may be bored to a trifle closer fit. Some extra good bearing linings may even be bored to a .004 in. fit and then allowed to surface in by running at no load until practically all heating has ceased, after which they may be placed in service. However, this is usually done only with metals which are superior to ordinary babbitt.

A step bearing used on a grinder or emery wheel where the bearing must withstand both ninety-degree and parallel thrust or pressures is shown in Fig. 4. This is an oil-lubricated bearing, but instead of using an oil ring the shaft rubs against an oil-soaked piece of wool waste and thus secures its lubrication. However, a compression grease cup could be used to force grease through the entire length of the bearing. Fig. 5 illustrates the main drive shaft bearings of an old type crane. I do not know whether or not this bearing is still standard with the company which manufactures this crane. Only one-half of a bearing, so to speak, is required as all of the weight rests upon the upper half of the bearing. The lower half of the shaft is left exposed to wipe lubrication from a grease box packed with wool waste

Fig. 2—Here is a good way to keep worn bronze bearings from the junk pile.
When brass or bronze sleeve bearings become worn down too far for satisfactory use they may be put back into service by boring out and babbitting, as shown at the left. The bearing at the right has not yet been placed in service. The particular bearings shown are used on a 15-hp. motor.



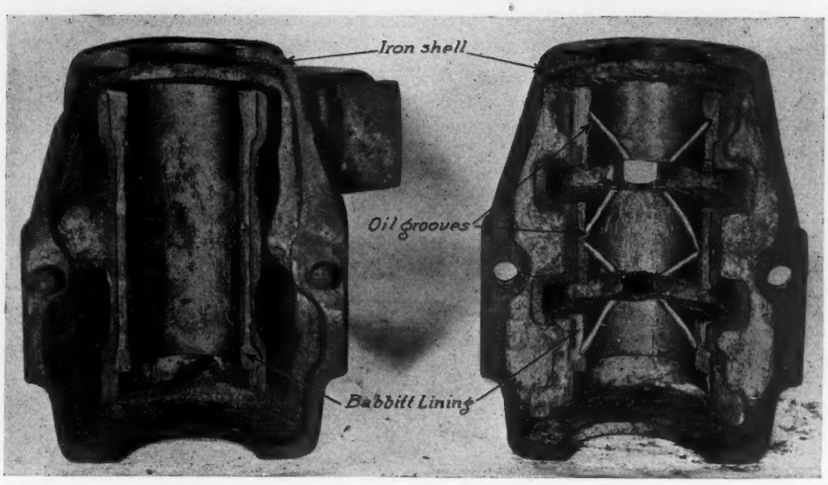


Fig. 3—Split bearing used on Westinghouse type CCL motor of 5-hp. to 15-hp. size.

The shell is made of iron, with a babbitt lining. These bearings are provided with two oil rings.

and oil or light, soft grease. The speed is slow and the shaft diameter large, so that the pressure per square inch is not great.

Babbitt Linings Are Cast to the Exact Size in a Steel Mold

According to conditions or shop practice, babbitt linings may be formed around the shaft which they are to support, or around a mandrel of suitable length and diameter.

The pouring of a babbitt sleeve in a steel mold which I have found very convenient is shown in Fig. 7. This mold makes the sleeve accurately to size. A rounded and semicircular ridge is provided on the mandrel to form an oilway or hollow in the babbitt lining for retaining grease, as this lining is used with grease lubrication. Fig. 8 shows a dissassembled view of this bearing mold with one-half of the babbitt lining removed. The reason for making this bearing mold accurately to the required size of the babbitt lining is because the outer surface of a babbitt lining seems tougher if no machine work is done on it, thus using against the shaft the surface chilled in the mold. It may also be noticed that the babbitt lining shown does not have to withstand any end thrust, as it is used upon a crane bridge lineshaft.

With bearings which are lubricated by oil some means must be provided for maintaining a constant flow of oil through the bearing. This is usually accomplished through the medium of oil rings which pass through slots cut in the upper portion of the bearing and ride on the top of the shaft, the lower portion of the ring passing through oil contained in a well under the bearing.

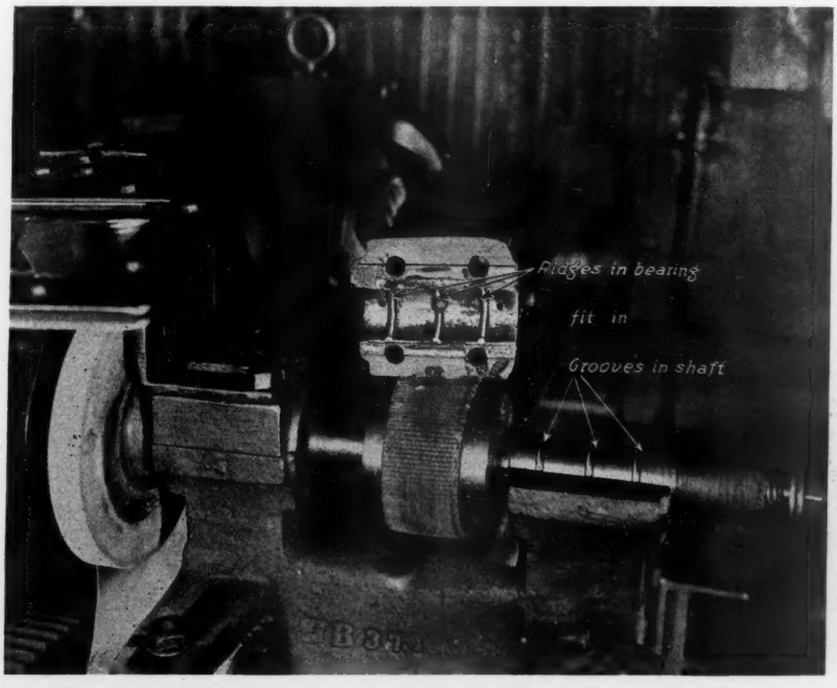


Fig. 4—A step bearing is used on this emery wheel to resist end thrust.

Ridges in the babbitt lining fit into corresponding grooves in the shaft and prevent lateral movement.

It may be said here that oil rings are always made of a non-magnetic metal when they are intended for use in electrical apparatus.

Oil Rings Must Be Carefully Selected to Obtain Best Results

After the oil-ring slot is cut the ends of the slot are filed at such an angle than the inner diameter of the oil ring cannot scrape or nearly scrape this metal edge in its rotation with the shaft. The slot width is made wider than the ring so that the oil cannot be scraped from the oil ring by the edges of the ring slot. In case the oil is scraped from the oil ring by the sharp edges of the oil ring slot, only a small portion of the oil carried up by the ring remains to flow from the ring to the shaft and thence through the bearing for lubrication. Inasmuch as this oil ring is depended upon for the lubrication of the bearing, it is essential to have a properly designed ring. Further, it must be a true circle, or practically so, or it will not revolve with the armature shaft. There will be enough slip at best between the oil ring and the shaft, so as much slip as possible may be eliminated without danger of flooding the bearing with oil. As a matter of fact, this is just what we wish to do, for the more oil flowing through a bearing in a given time the better the results. Therefore, an oil ring that will retain or carry up as much oil as possible should be selected. A very good type is one made of a rectangular piece of metal formed into a ring, or turned in a lathe.

In Fig. 9 five types of oil rings are shown. Fig. 9*A* illustrates a V-type oil ring or, it may be said, an inverted V-type ring. This ring has a tendency to allow a good portion of the oil to slide off before reaching the top of the shaft or even before reaching the oil slot in the bearing. The knife edge formation also seems to cut through the oil and reduce the dragging action so that less than the maximum amount of oil

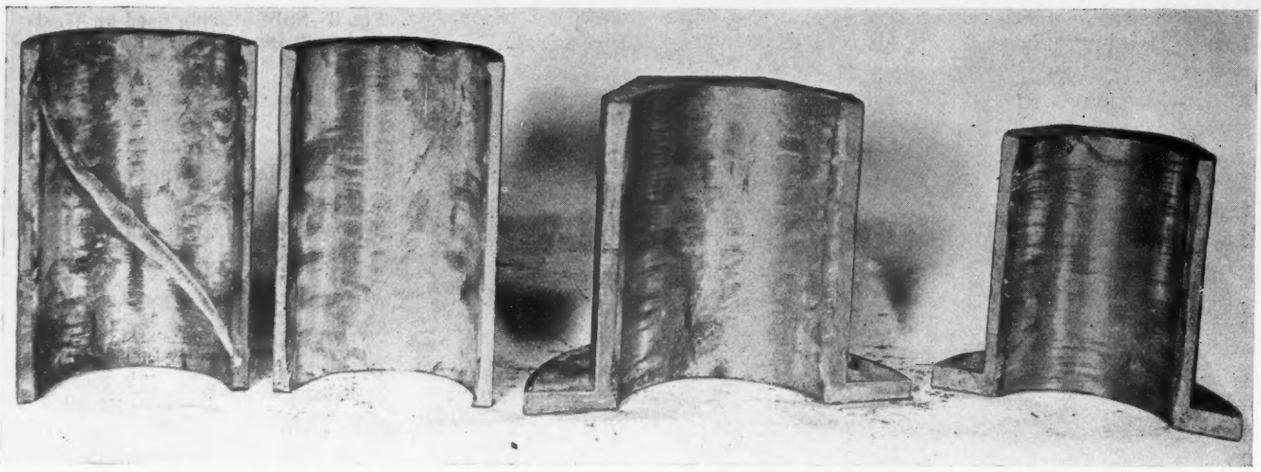


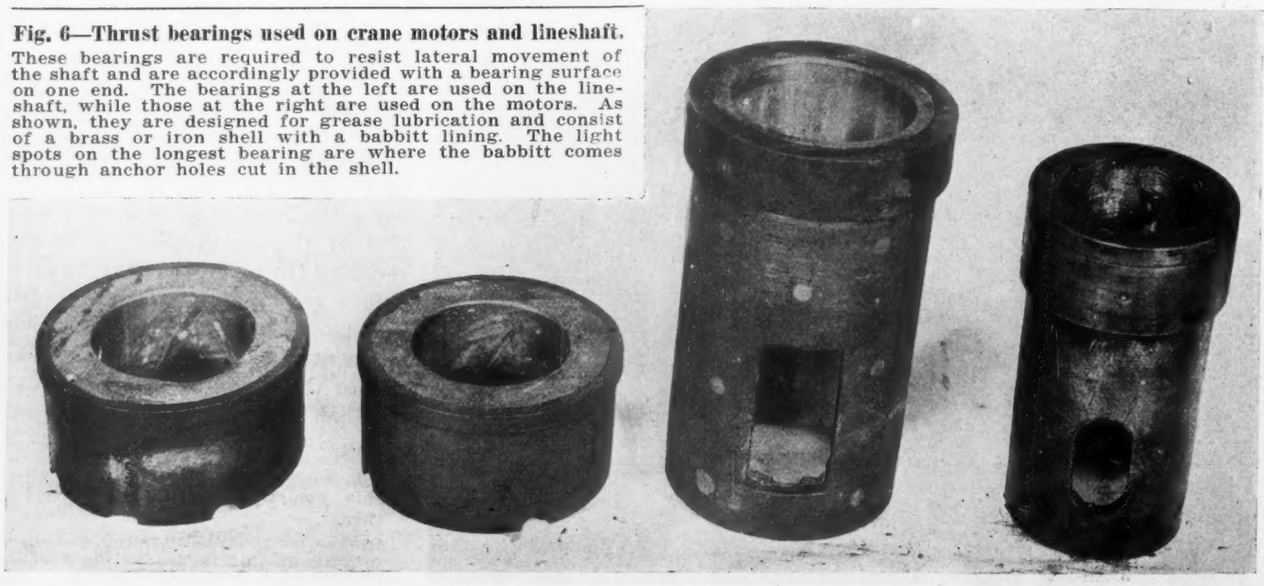
Fig. 5—These split bearings are used on cranes.
The two babbitt bearings at the left support the drive shaft. At the right are the main bearings, supporting the crane bridge, designed to withstand end thrust. Both types are grease lubricated and are made in steel molds described in the text.

is carried into the slot in the bearing. Also, at high speed this ring acts as a mist collar or oil slinger, similar to those upon the shaft to prevent oil from creeping along the shaft out of the bearing housing, throwing a portion of the oil off at the point of the V. However, owing to the small vertical portion of this oil ring, only a small amount of oil is wiped off the sides by the oil ring slots. Fig. 9*B* is a straight-sided, rectangular oil ring cut at the desired widths from a cylinder of the correct diameter. It has a full vertical side and thus gets the maximum wiping effect of the oil-ring slot. The top is parallel to the outer surface of the shaft upon which it is rotating. This oil ring depends upon the top and one side for lubricating the bearing, but costs little to make. Fig. 9*C* is a very good oil ring having no edges from which to throw oil. It has a good pitch from the center of the outer diameter to the outer edges of the inner diameter, with a large area for oil carrying. This ring should have practically the same pulling power as other types of rings of the same approximate weight. The main drawback is the expense of making this ring, as the outer semi-circular surface would probably have to be turned out upon a lathe if anything except a hard, tough, white metal is used. It might be possible to pour this white metal in a really good mold. Fig. 9*D* is about as good and cheaply made an oil ring as ordinary motor sleeve bearings would require at average motor speeds. It has practically the same amount of contact upon the shaft for load pulling, with a small wiping edge to wipe against the sides of the oil-ring slot, and enough bevel at each top edge to give sufficient pitch to carry oil readily from the flat top surface down the angular sides to the shaft, which then carries the oil into the bearing. The edges formed by the flat top and the angular sides do not make an acute angle and therefore will not have such a tendency to throw oil as the oil ring shown at Fig. 9*A*. There is enough flat top left to drag the oil up from the oil well and to reduce the cutting-through feature of an oil ring to a minimum. The bevel at each edge is not extensive and therefor the scrap material is not great. Fig. 9*E* illustrates a split oil ring which is often found in motors and generators of the pedestal split-bearing type.

Oilways Are Cut in the Bearing to Insure Proper Lubrication

After the oil is carried by the ring from the oil well to the top of the revolving shaft, it must be allowed to flow through the bearing sleeve, and it must reach all parts of the bearing sleeve or a hot spot and a hot bearing will result. Therefore

Fig. 6—Thrust bearings used on crane motors and lineshaft.
These bearings are required to resist lateral movement of the shaft and are accordingly provided with a bearing surface on one end. The bearings at the left are used on the lineshaft, while those at the right are used on the motors. As shown, they are designed for grease lubrication and consist of a brass or iron shell with a babbitt lining. The light spots on the longest bearing are where the babbitt comes through anchor holes cut in the shell.



oilways or grooves leading from the oil-ring slot are cut in the inner surface of the bearing. After reaching the top of shaft, the oil follows the shaft in its rotation until it reaches the end of the oil-ring slot, toward which the shaft is rotating. Of course, some oil runs off the oil ring at the opposite end of the oil-ring slot, and thus oil is supplied at each end of the slot. Now at the end of the slot towards which the top of the shaft rotates there is a suction or drawing-in force between the rotating armature shaft and the inside of the sleeve bearing. This draws in the oil which then flows along the oilways from the slot, which is usually somewhere near the center of the bearing, toward each end of the bearing. In order to lubricate properly all parts of sleeve bearings these oilways must carry the oil from the center to the ends and the oil in this travel is wiped from the oilways as the shaft rotates, spread over the inner surface of the sleeve and finally runs out at the ends of the sleeve. It is necessary to secure an ample flow of oil through the oilways so that a substantial oil film may be obtained between the outer surface of the shaft and the inner surface of the sleeve, otherwise heating and abnormal wear will occur.

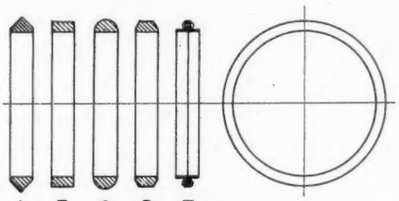


Fig. 9—Types of oil rings used for lubrication of bearings.

There are several different practices in cutting oilways. One method is to cut a horizontal oilway parallel with the axis of the shaft and touching the inner ends of the oil-ring slot. Usually the side of the oilway farthest from the oil-ring slot is cut shallower than the side into which the slot enters. Sometimes oilways are cut around the ends of the sleeve and sometimes they are omitted. The bearings at the right in Fig. 11 illustrate oilways cut at an angle, sloping downward toward the ends of the sleeve, but not extending through to either end. This gives what I would call partial lubrication and I would not advise the use of oilways cut in this manner, although it is frequently done, with apparently satisfactory results. One of the disadvantages of this kind of oilway is that if the oilway is stopped before reaching the end of the sleeve and no provision is made for washing grit from the oilway it must either

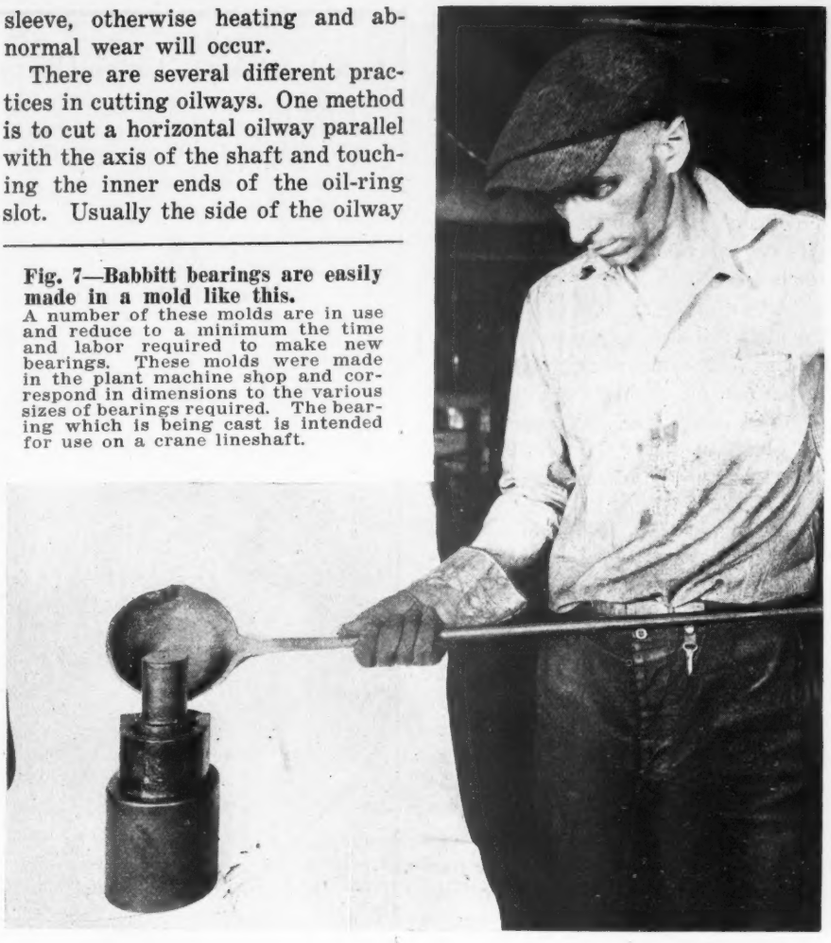
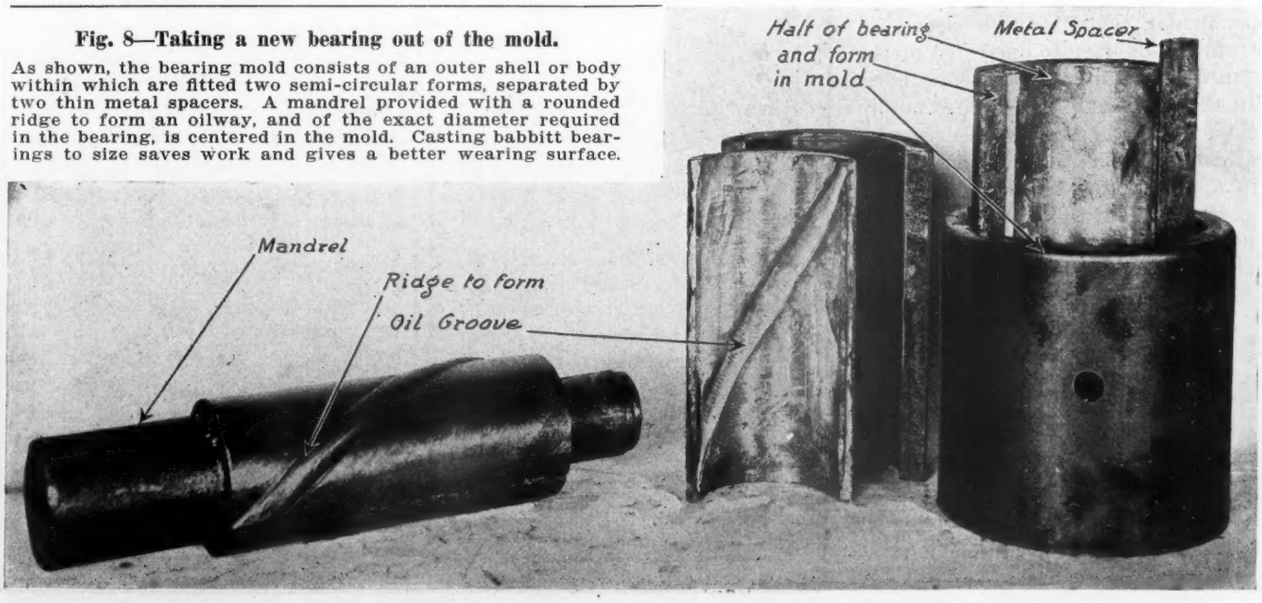


Fig. 7—Babbitt bearings are easily made in a mold like this.
A number of these molds are in use and reduce to a minimum the time and labor required to make new bearings. These molds were made in the plant machine shop and correspond in dimensions to the various sizes of bearings required. The bearing which is being cast is intended for use on a crane lineshaft.

Fig. 8—Taking a new bearing out of the mold.
As shown, the bearing mold consists of an outer shell or body within which are fitted two semi-circular forms, separated by two thin metal spacers. A mandrel provided with a rounded ridge to form an oilway, and of the exact diameter required in the bearing, is centered in the mold. Casting babbitt bearings to size saves work and gives a better wearing surface.



remain in the oilway or be forced out and become imbedded in the babbitt sleeve or shaft. If the grit is hard and cuts its way into the babbitt lining it will eventually scratch a ring around the shaft of a width equal to the end play or lateral movement of the shaft. Also, if the oilways are dead-ended or do not form a complete circuit of flow, only a certain quantity of oil can pass through the sleeve in a given length of time. Inasmuch as foreign matter cannot be washed out of these oil grooves, they tend to become filled up and cut down the oil flow still further. This reduced quantity of oil passing through the bearing may in turn cause higher operating temperature with all of the attendant evils which this condition brings about.

In the bearings at the left in Fig. 11 I have shown what I believe to be the proper way of cutting oilways and oil-ring slots. I have used this method on the motors in cement mills, smelting plants and elsewhere and the bearings have given good results. The oil-ring slot is cut one and one-quarter to one and one-half times the width of the oil ring. As will be seen, the oilways are cut at an angle downward and parallel with the shaft and are cut through the length of the sleeve from the oil-ring slot to another oilway or draining groove turned in the inner diameter or bore of the sleeve. The angle downward of the oilways from the oil-ring slot to the draining grooves at the end of the bearing are lower at the end by about one-quarter to one-third the distance from a horizontal center of the sleeve to a perpendicular center of the sleeve, or from one-quarter to one-third of the quarter section of the sleeve bore. In the bottom of this groove cut in the ends of the bearing sleeve there are drilled from one to three holes of approximately the same diameter as the width of this groove. If three holes are (*Continued on page* 309)

Graphic Charts Taken During Test on New Bearing Metals

At the left is the wattmeter reading for the motor when equipped with a 70-lead, 30-copper bearing. Chart at right shows load when the Ackermite bearing was tested. The heavy loads indicated at various points on the chart were several times caused by particles of bearing metal worn off by the friction being sucked in by the fan on the rotor and lodging between the rotor and stator. On several occasions the load on the motor was so great that the generator load had to be thrown off. There was also some variation in the load imposed by the water rheostat, which in time became boiling hot, while the high temperature of the bearings undoubtedly affected the load both by increasing it and by causing some of the variations indicated.

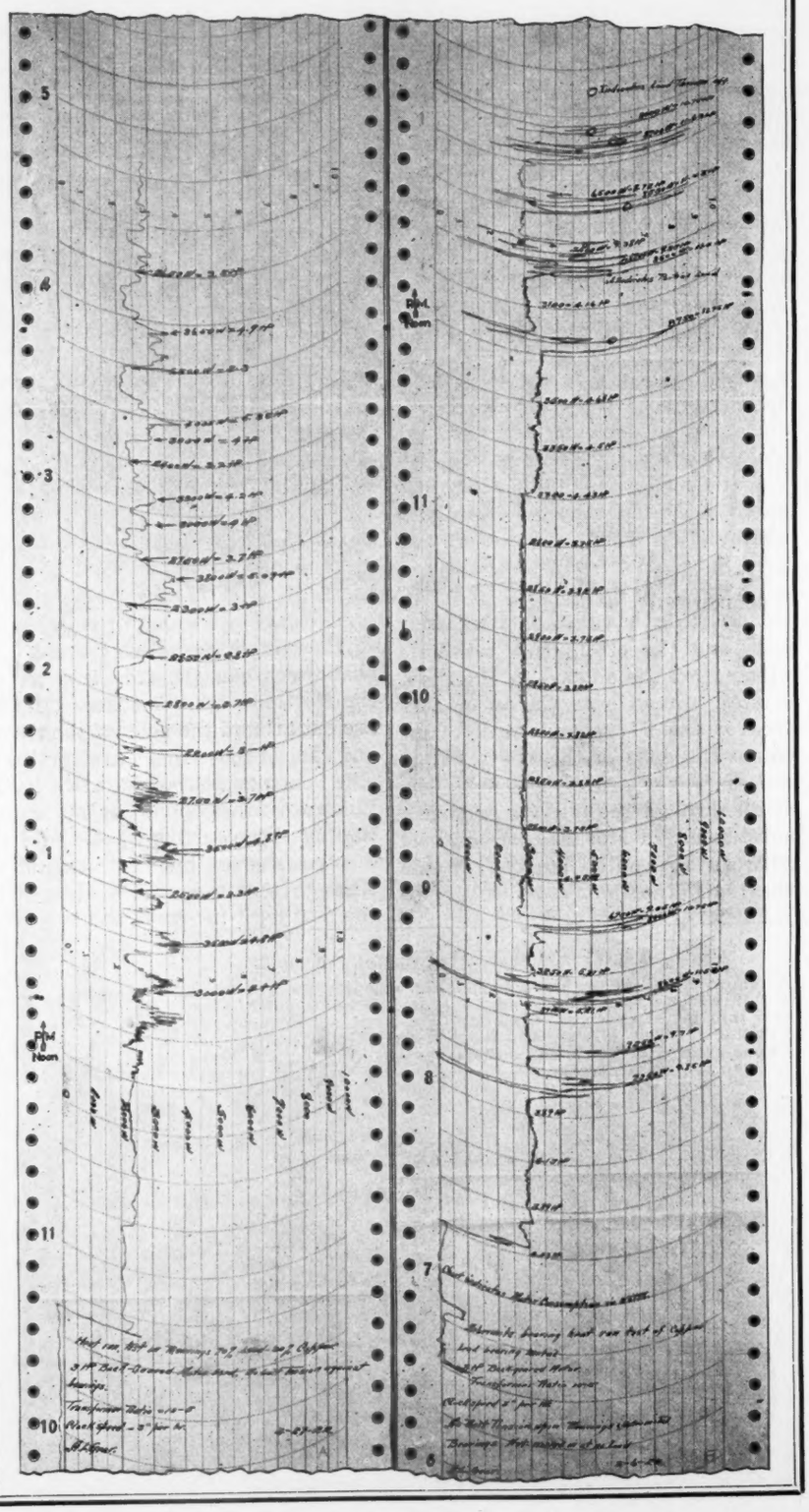


Fig. 10—These diagrams show the load conditions when two new bearing metals were tested.

In making these tests the bearings were first machined to the proper size and allowed to work in on a 3-hp., 3-phase, 60-cycle, squirrel cage, back-geared motor running under normal conditions of load and lubrication. With the Ackermite bearing 243 hours were allowed. The bearing housing and oil well were then washed out with gasoline and wiped dry, after which the motor was placed under test by belting it to a 10-kw. 220-volt, direct current generator loaded by a water rheostat.

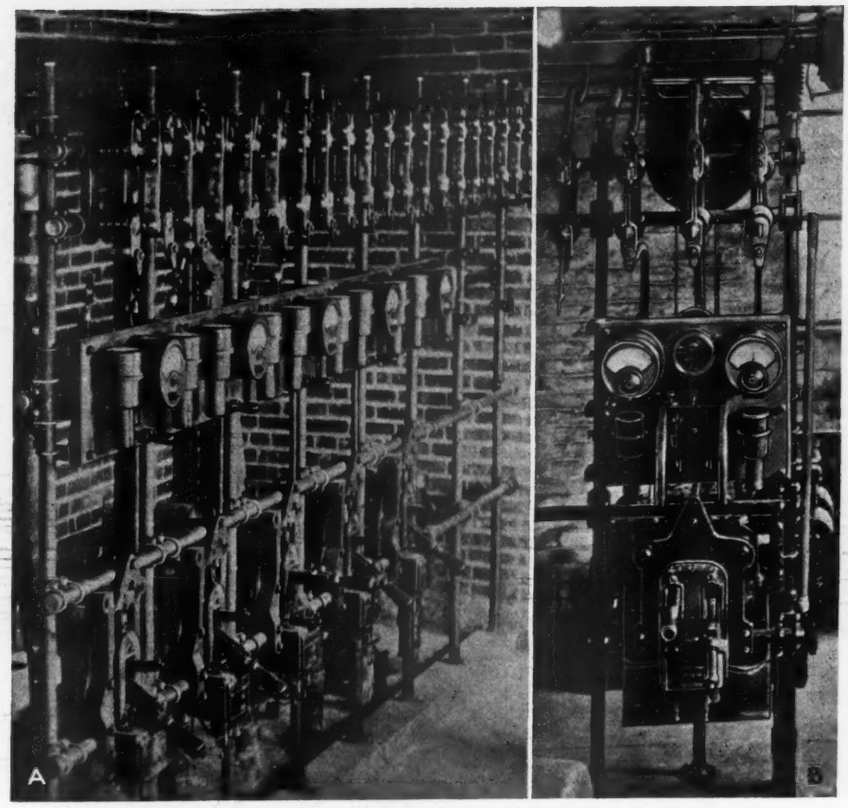
How to Make Up

Motor Service Panels with Standardized Equipment

for Quick Changes New Requirements and Repairs

By C. H. MATTHEWS

Electrical Engineer, M. A. Hanna & Company, Cleveland, Ohio



The parts used in making up the row of feeder panels at the left and the synchronous motor panel at the right are given in the master list of materials on page 273, for these and other standard units shown in the wiring diagrams of Fig. 1.

FOR controlling large motors in industrial plants and in substations that provide service to different departments it is desirable to have switchboard panels on which the apparatus can be shifted or exchanged without the necessity of substituting a board of entirely different construction. The use of the same parts on different kinds of boards also allows a smaller stock of replacement material to be carried on hand and assures quick repairs. In plants of this company, switchboards consisting of various standard parts assembled to form completed units have proven economical and sufficiently refined for the requirements of individual motors and outlying substation installations. The drawings and photographs accompanying this article show some of the various panels built up for 2200-volt motors, incoming lines and feeder circuits.

For each panel there is an assembly drawing and a wiring diagram. A master list of materials (see page 273) is made up, including all of the parts used on all of the standard types of panels adopted. The list describes each part in detail and each item listed has been given a designated letter. Then for each panel a table (see page 311) is made giving the number of each one of the parts required for a particular job. The table on page 311 shows the parts required for each of five different types of panels. Sometimes the master list refers to an assembled unit which forms one part of the complete panel. The master list for such a unit gives a drawing number as well as the name of individual items which go to make up the unit.

THE DETAILS of installation practice which Mr. Matthews outlines in this article represent operating experience in a wide variety of industrial works. The M. A. Hanna & Company operates plants in twenty-one cities throughout the Middle West, Pennsylvania and West Virginia, and fourteen steamship transportation lines with loading and unloading docks.

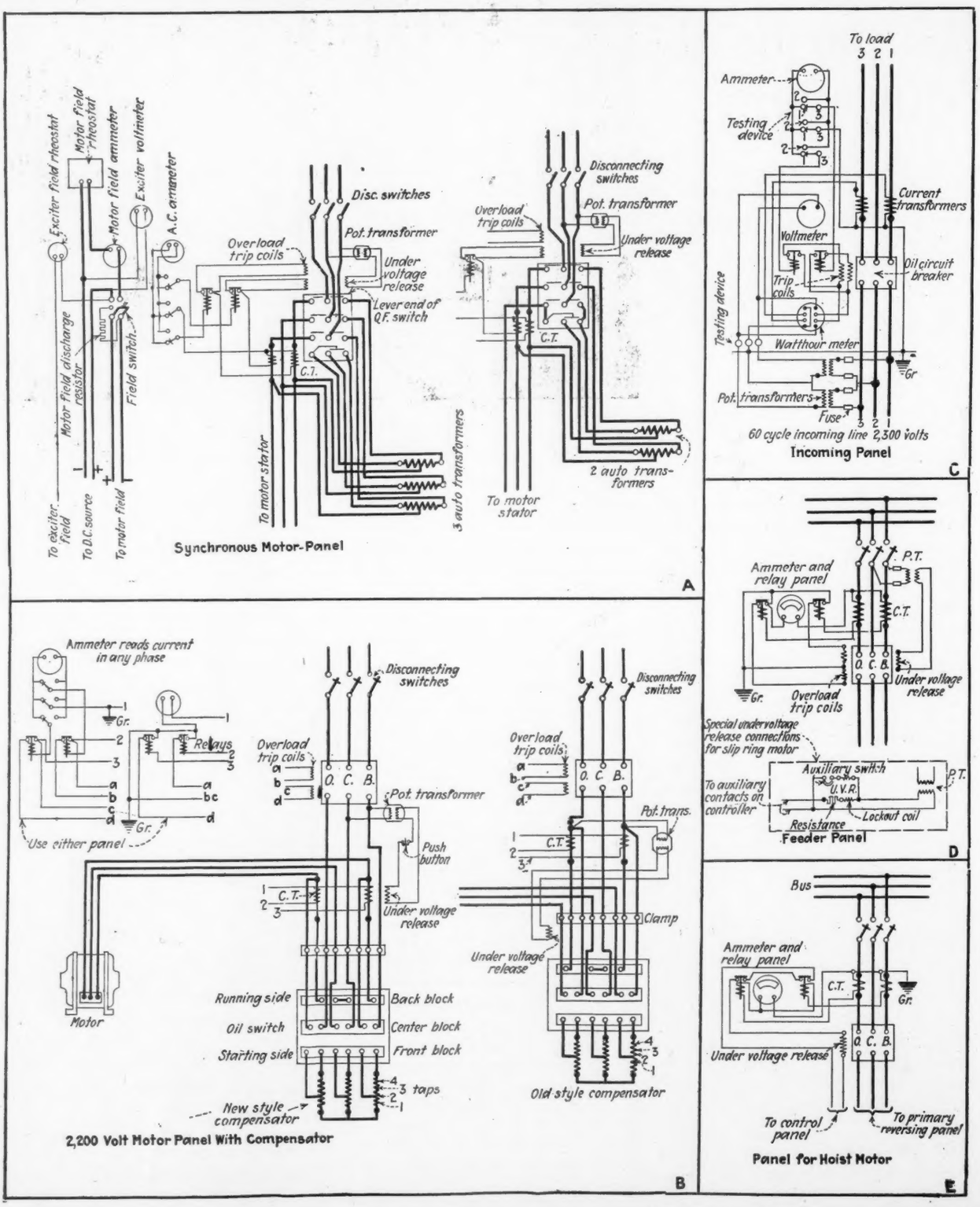
MR. MATTHEWS points out that the various standard panels shown have not only proved economical and convenient in operation but sufficiently refined for individual motor service and outlying substations. Moreover, they make it possible to keep on hand an adequate stock of replacement material for quick repairs and changes.

The panel supports are all of 1¼-in. black steel pipe and standard fittings are used throughout. The disconnecting switches are 300, 600 and 800 amperes in rating and are equipped with safety catches if needed. The relays are of the 5-amp. inverse-time-limit circuit-opening type. For service such as that for mine hoists, where the ammeter scale would have to be about 200 per cent of the trip setting on the oil circuit breaker, the relays should have 2-amp. or 3-amp. coils, so that only two current transformers would be necessary instead of two current transformers for the relays and another for the ammeter. The ammeter in this case should have 5-amp. coils and its scale rating should correspond to the rating of the current transformers.

The five types of panels shown with this article are, respectively, for an incoming line, a slip-ring motor, a feeder circuit, a synchronous motor and a squirrel-cage motor. The panel for an incoming line is shown in *C* of Fig. 4 and the wiring diagram is shown in *C* of Fig. 1.

Fig. 1.—Wiring Diagrams for Different Types of Motor and Feeder Panels

A—Connections of the synchronous-motor panel shown in the right-hand side of the illustration on page 271 and at A of Fig. 3. In this wiring diagram at the left is shown the connection for three autotransformers, while at the right is that for two autotransformers. B—Connections for a squirrel-cage motor operated on a 2200-volt compensator. This panel is shown at B of Fig. 3. In the wiring diagram the drawing at the left shows the connections for the new-style compensator CR-1034-N1, and P1, of the General Electric Company. The connection at the right shows the CR-1034 compensator of the same company, which is an older type. At the left-hand upper corner of this drawing are shown two possible connections for an ammeter. The one at the extreme left shows an ammeter switch which may be used to read the current on any phase, while the smaller diagram at the right shows an ammeter permanently connected in one phase. C—A panel for an incoming 2200-volt line. Two elevation views of this panel are shown in C of Fig. 4. D—This panel is used either for a feeder or for a slip-ring induction motor. The small drawing at the bottom shows the special connections to the controller of a slip-ring induction motor. A feeder panel is also shown in E of Fig. 4, and in Fig. 2 and the head-piece illustration are photographs of feeder panels. E—A panel for service to a hoist motor. See panel in E of Fig. 4.



Master List of Materials and Parts for Switchboard Panels

This is a complete list of parts required for making up all of the panels shown in the accompanying illustrations. It is used with the table on page 311 which gives the number of these parts required for five different panels. In this table the following abbreviations are used: (G. E. Co.) for General Electric Company; (E. E. E. Co) for Electrical Engineers Equipment Co.; (E. P. E. Co.) for Electric Power Equipment Corporation; (D. S. E. Co.) for Delta-Star Electric Company, and (W. E. M. Co.) for Westinghouse Electric & Manufacturing Company.

MARK **EQUIPMENT**

(A) 1¼-in. pipe, 90 in. long, threaded one end.

(B) 1¼-in. pipe, 68 in. long, threaded one end.

(C) 1¼-in. pipe, 24½ in. long, threaded one end.

(D) 1¼-in. pipe, 26 in long.

(E) 1¼-in. pipe, 21 in. long, threaded one end.

(F) 1¼-in. pipe, 42 in. to 48 in. long, depending upon controller used.

(G) 1¼-in. pipe, 56½ in. long, threaded one end.

(H) 1¼-in. pipe, 86½ in. long, threaded one end.

(I) Cross clamp for 1¼-in. pipe, G. E. Co. No. 1943357G28; E. E. E. Co. No. 5186; E. P. E. Co. No. 6313.

(J) Oval floor flange for 1¼-in. pipe, G. E. Co. No. 1403580; E. E. E. Co. No. 1651; E. P. E. Co. No. 6313.

(K) Clamp tee for 1¼-in. pipe, G. E. Co. No. 1943356G2.

(L) Double panel supports for 1¼-in. pipe, G. E. Co. No. 1943358G14; E. E. Co. No. 1623; E. P. E. Co. No. 6417.

(M) Double panel supports for (2) 1¼-in. pipes, G. E. Co. No. 1943359G23; E. E. Co. No. 9458.

(N) Pipe caps for 1¼-in. pipe, G. E. Co. No. 41647; E. E. E. Co. No. 9701.

(O) "U"-bolts with nuts for 1¼-in. pipe, E. E. E. Co. No. 9501 or 9505; E. P. E. Co. No. 6533 or 6534.

(P) ⅜-in.x2-in. lag screws.

(Q) ½-in.x2½-in. lag screws.

(R) $\frac{5}{16}$-in.x2½-in. machine bolts.

(S) ½-in.x2½-in. machine bolts.

(T) $\frac{5}{16}$-in.x1½-in. machine bolts.

(U) Piece 1¼-in. conduit for overload trip-coil leads.

(V) Potential transformer for use on 2200-volt panels only.

(W) Current transformers:
G. E. Co. Type W-2 on panels D in Fig. 4 and B in Fig. 3.
W. E. M. Co. Type KA on panels A in Fig. 3, C in Fig. 4 and E in Fig. 4.

(X) D. S. E. Co. s. p. s. t., 6000-volt, (Type J2U-14) disconnecting switches with U-bolts for mounting on 1¼-in pipes, complete with terminals.
300-amp. switches, Dwg. No. 21746 (not shown).
600-amp. switches, Dwg. No. 21929 (not shown).
800-amp. switches, Dwg. No. 21930 (not shown).
(One 4-ft. switch stick for each installation.)

(Y) W. E. M. Co. automatic oil circuit breaker having 5-amp., double-coil, instantaneous overload trip.
Type F-2: Style No. 186260, 300 amp.; Style No. 186276, 500 amp.; Style No. 198806, 600 amp.
(Style No. 215185 separate pipe-mounting bracket.)
Type F-3: Style No. 209584, 500 amp.; Style No. 209587, 800 amp.
(Style No. 215187 separate pipe-mounting bracket.)
All breakers to have standard overload trip coils, except those used with hoist-type induction motors using magnetic control, which will have under-voltage release attachment with coils of same voltage as control circuit. Overload trip will be accomplished by opening the under-voltage release coil by means of circuit-opening relays.
Breakers on panels with slip-ring induction motors using drum controller to have special under-voltage release attachment with magnetic lock to prevent closing of breaker until controller has been brought to the "off" position.

(Z) W. E. M. Co. Type "QF" motor-starting oil circuit breaker having double-coil, 5-amp. instantaneous overload trip and under-voltage release attachment and a special steel plate supporting bracket.
Style No. 246401, 7500 volt, 300 amp.
Style No. 246402, 4500 volt, 600 amp.

(AA) Drum-type controller, having contact on "off" position for magnetic interlock with oil circuit breaker, complete with necessary grid resistor.

(BB) Self-contained, hand-operated starting compensator, having under-voltage release attachment but without overload relays.

(CC) G. E. Co. slate base, 20-x24-in.x1½-in.
1—Type R-6, A. C. voltmeter.
1—Type R-6, 5-amp. ammeter.
1—Polyphase integrating watthour meter.
2—S.p. circuit-opening, plunger-type, inverse-time-limit overload relays having 5-amp. coils.
1—Set of current transfer and testing receptacles with plugs.
6—Cat. No. 174545 panel bolts.
1—Set of potential transfer and testing receptacles with plugs.

(DD) G. E. Co. (Dwg. K-2103146) slate base, 12-in.x24-in.x1½-in.
1—5-amp. R-6 ammeter.
*2—S.p. circuit-opening, plunger-type, inverse-time-limit overload relays having 5-amp. coils.
**1—Card holder.
**1—Set of current transfer and testing receptacles with plugs.
**1—Set of potential transfer and testing receptacles with plugs.
4—Cat. No. 174545 panel bolts.

(EE) G. E. Co. (Dwg. K-2158114) slate base, 20-in.x24-in.x1½-in.
1—5-amp. R-6 A. C. ammeter.
1—R-6 field ammeter.
2—S.p. circuit-opening, plunger-type, inverse-time-limit overload relays having 5-amp. coils.
**1—Card holder.
**1—Set of current transfer and testing receptacles with plugs.
1—D.p.s.t. field switch with discharge resistance clips and barriers.
6—Cat. No. 174545 panel bolts.
1—Rheostat-operating mechanism.
(Cat. No. 1870360G4 chain-operated for use with synchronous motor without individual exciter.)
(Cat No. 1870360G7 concentric mechanism for use with synchronous motor with exciter.)

(FF) $\frac{3}{16}$-in.x1-in.x28-in. steel strap.

(GG) ¼-in.x1½-in.x28-in. steel strap.

(HH) ¼-in.x1½-in.x1½-in. angle, 28 in. long.

(II) Set of autotransformers.

(JJ) G. E. Co. or Cutler-Hammer Mfg. Co. plate-type, 3-point-support exciter field rheostat (not to exceed three 15-in. plates).

(KK) Synchronous-motor chain-operated field rheostat with sprocket and 5 ft. of chain.

(LL) Rheostat chain guides consisting of:
1—G. E. Co. No. 1695721 chain idler.
4—G. E. Co. chain-idler pulleys.
1—E. P. E. Co. No. 6105 double clevis.
2—$\frac{7}{16}$-inx4¾-in. machine bolts.

(MM) Synchronous-motor field-discharge resistor.

(NN) G. E. Co. Type D-12 exciter voltmeter.
W. E. & M. Co. Style No. 127768 mounting bracket.

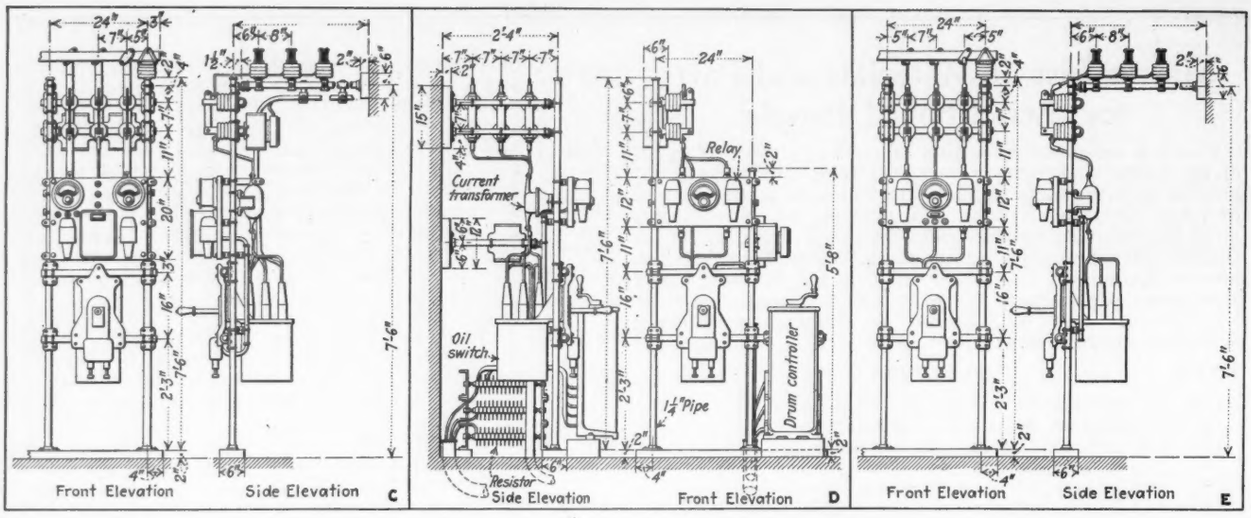
(OO) Necessary wire, cable, conduit and condulets, depending upon installation.

(PP) Bus-bar supports for mounting on 1¼-in. pipe.
(Mount supports on every second back brace.)
¼-in.x2-in. bus-bar, copper, 27 in. long, for first and last panels and 24 in. extra for each intermediate panel.
W. E. M. Co. Style No. 196395 bus-bar terminal and Style No. 196305 bus-bar clamps, with necessary bolts. (Three required per panel.)

(QQ) E. P. E. Co. Type "RSS" bus supports for 1¼-in. pipe for supporting incoming or outgoing cables.

*For hoist service, relays to have 2-amp. or 3-amp coils.

**Optional items.



The panel has oil switch, relays, current and potential transformers, watt-hour meter, ammeter, voltmeter, etc. A list of the materials used is shown in the fourth column of the table on page 311.

For slip-ring induction motors controlled by an oil circuit breaker and drum controller, the usual operating requirements are satisfactorily met by a panel like that shown in *D* of Fig. 4. The wiring diagram for the primary connections is shown in *D* of Fig. 1. The drum controller and resistance are mounted with the panel to form a compact unit. The controller chosen for this service is equipped with an auxiliary contact on the "off" position for magnetically interlocking with a special under-voltage release and lockout coil on the oil circuit breaker to prevent closing the oil circuit breaker except when the controller is on the "off" position. These special connections are shown at the right hand of the drawing in *D* of Fig. 1. This arrangement can be used on motors up to 600 hp., 2200 volts. For larger motors, magnetic control should be employed. The controller and resistance can, of course, be located at a distance from the panel near the motor if desired.

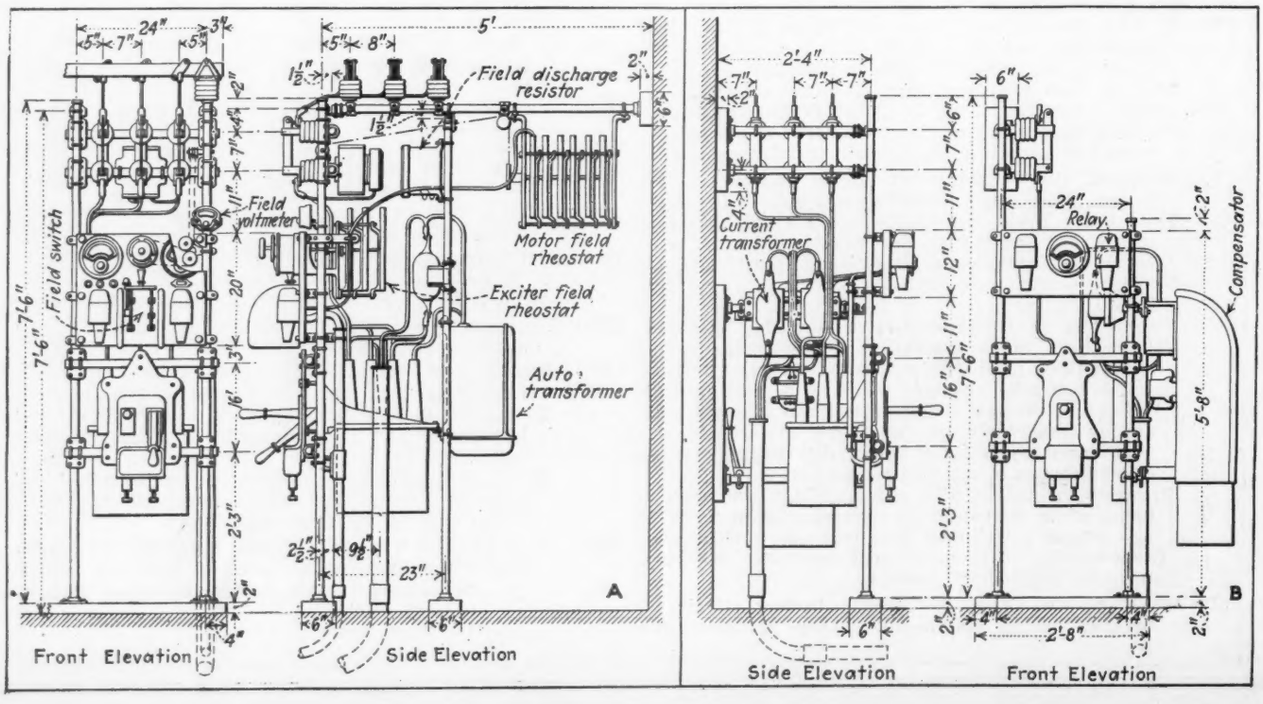
A simple feeder panel is shown in *E* of Fig 4, in Fig. 2, and on the left-hand side of the illustration on page 271. Wiring diagram is shown in *B*, Fig. 1. (*Continued on page* 311.)

Fig. 3—Standard types of panels for synchronous and squirrel-cage motors.

A—This is a synchronous-motor panel of which the wiring diagram is shown in A of Fig. 1 and a photograph is shown at the right in the illustration on page 271. B—A panel for a squirrel-cage induction motor with wall-mounted, self-contained compensator. The wiring diagram is shown in B of Fig. 1. The materials needed for each of these panels may be found on the accompanying tabulation on page 273.

Fig. 4—Construction drawings for standardized switchboard panels.

C—This is a panel for an incoming 2200-volt line. For the wiring diagrams see C in Fig. 1 and for a list of materials see accompanying table, page 311. D—Panel for feeder or slip-ring induction motor with secondary drum controller and resistance. The wiring diagram is shown in D of Fig. 1, and the material list is shown in the table on page 311. E—A 2200-volt feeder panel. The wiring diagram for this panel is shown in D of Fig. 1, while photographs of panels of this kind are shown in Fig. 2 and at the left-hand side of the illustration on page 271. The list of materials is given in the tables on pages 273 and 311.



WIRT S. SCOTT *Says:*

Electric Ovens Are A Good Investment

And He Gives Figures and Facts That Prove It

MR. SCOTT explains the flexibility and ease of heat control, freedom from gases and low maintenance and shows why automatic conveyors for dipping parts in enamel and carrying them through ovens are particularly effective with electrical heating.

To the marked advances made during the past six or seven years in applying electric heat to industrial purposes Mr. Scott has contributed much in the development of electric ovens. As manager of the industrial heating section of the Westinghouse Electric & Manufacturing Company, his field of observation has been wide and his sources of information have been many. Owing to his broad knowledge of this field, Mr. Scott was chosen by the New England section of the National Electric Light Association last year as one of the experts to direct a short course in industrial heating applications. He is now associated with a more extensive course being conducted in several sections of the country.

BEFORE discussing the uses and operating features of electric ovens for baking or heat treating; how uniformly the ovens are heated; how easily they are held at the right temperature, and how cheaply they do their work, it is important to know something of the history of their development, and the steps that have been taken to make them applicable to a wide range of work.

Much of the development of industrial heating within the past six years is due to the demands of a single industry; namely, automobile manufacturing. When electric heating equipment was first installed in old gas ovens as an experiment, it demonstrated its superiority over gas by reducing the time for baking from four hours to one hour, but at a greatly increased cost of operation. Attention was then turned to better insulation of ovens and construction best suited to electric heaters.

Importance of Proper Ventilation

With gas ovens, a great amount of ventilation was used in order to supply sufficient oxygen for combustion purposes. Since the air had to be heated up to a temperature several hundred degrees higher than the maximum operating temperature it was obviously a source of considerable loss, sometimes amounting to 50 per cent or more of the total heat generated. The next step in development was to attempt enameling with restricted ventilation and with no ventilation at all. Explosions resulted in these trials, as the volatile vapors contained in the solvent are highly explosive when mixed with the proper amount of air. Furthermore, in cases where no ventilation was used the work remained tacky, or not baked hard, as the oil in the enamel was not oxidized. Tests on an experimental oven proved that explosions could be obtained at temperatures as low as 450 deg. F. and after the heaters had been cut off for five minutes, by admitting air slowly into the oven until the proper mixture was reached. Further tests showed that the vapors from the solvent first flowed downward to the floor of the oven.

As a result of these experiments, it was realized that ventilation was of considerable importance. It was found that the amount of air forced into an electric oven could be reduced to approximately one-half of that required by a gas oven and, furthermore, that an oven should be ventilated near the floor line instead of at the roof. Low-level ventilation had three very important advantages: 1. The volatile vapors were withdrawn more quickly from the oven; 2. The heat convection currents from the heater flowed upward and then downward through the work, utilizing heat that otherwise would be wasted; 3. At the same time the heat was forced toward the center of the oven and floor, which part of the oven tends to be the coolest. This resulted in a more uniform temperature condition throughout the oven and, with the volatile vapors removed as rapidly as formed, much less air could be used.

Electric heat treating gives better results than any other method because of easier control and absence of fumes. This furnace has a maximum temperature of 2000 deg. Fahr.

One of the first ovens to be put in operation using floor ventilation was equipped also with roof ventilation in case the former method failed. Tests could therefore be made on both methods. It was found that with floor ventilation 20 kw.-hr. were required for ventilation alone, against 35 kw.-hr. for roof ventilation. Furthermore, in the former case, the work was completely baked

in 30 minutes, against 40 minutes in the latter, showing the effect of uniform heating.

As a result of these various investigations and a concentrated effort to lower the operating costs, the engineers of the automotive industry began to see the possibilities of electric heat in place of gas. The development of automatic temperature control for electric ovens was of the greatest importance in eliminating spoiled material. Thorough investigations were made as to the cost of every item entering into the baking of the enamel on each piece, and, while in every case the power bill for electric current exceeded the gas bill, the actual cost per piece of finished product was less.

Another development which saves money is the continuous oven, which was made possible only by application of electric heating units. Tests can be made to determine definitely the exact location required for the heaters to give the desired results, and once this is settled, the conditions within the oven remain fixed. Electric heaters being in relatively small units (as small as 2½ kw. each), easy to install and flexible in their installation, may be moved about in the oven until the proper temperature curve is obtained. In baking enamels requiring, say, a one-hour bake at 400 deg. F., the temperature should increase slowly as the work travels through the oven and at the end of 45 minutes, should reach the 400 deg. zone, and remain at that level for 15 minutes. Electric heaters supplemented by automatic temperature control offer an ideal solution to such problems.

Six Advantages of Electric Ovens

[1]

REDUCTION in amount of rejected work and the necessity of refinishing parts, due to temperature of ovens being continuously and automatically maintained at the desired baking temperature.

[2]

IMPROVED quality of product due to definite temperature control, uniformity of temperature throughout the oven, and elimination of products of combustion obtained when gas is burned directly in the oven.

[3]

REDUCED fire risk due to ease of controlling ventilation and elimination of gas fuel.

[4]

ECONOMY of the continuous-conveyor type oven made possible by the use of electric heaters.

[5]

GREATER speed of production due to uniformity of heating.

[6]

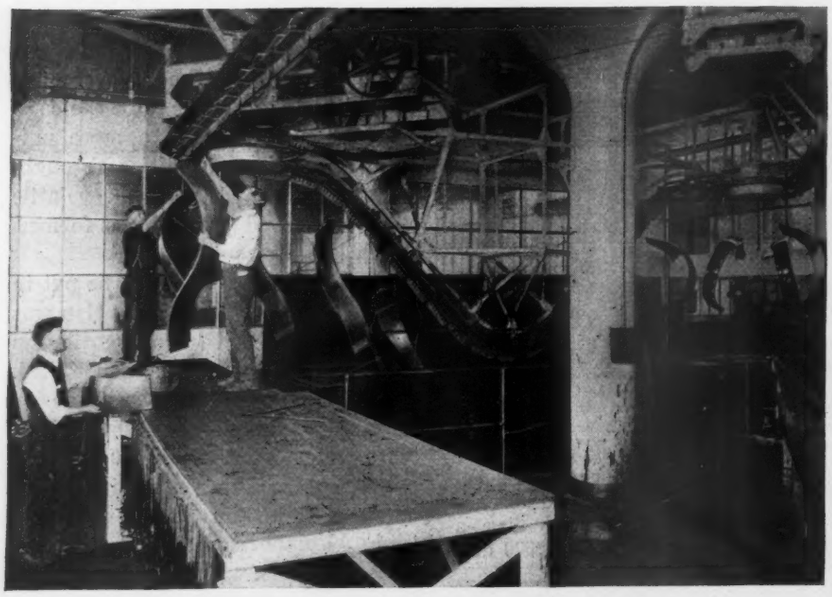
LOW production costs due to few rejects, increased speed of production, decreased labor, and decreased fire insurance rates.

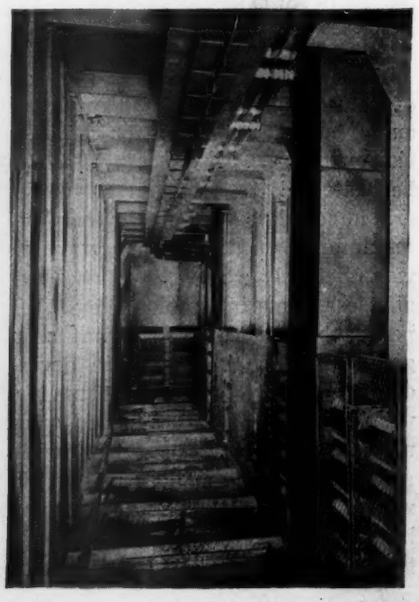
This simple overhead conveyor dips automobile fenders in the tank at the back of the room and then carries them through six electrically heated corridors like the one shown in the smaller picture at the right.

Points to Consider When Comparing Electric Heat With Gas and Oil

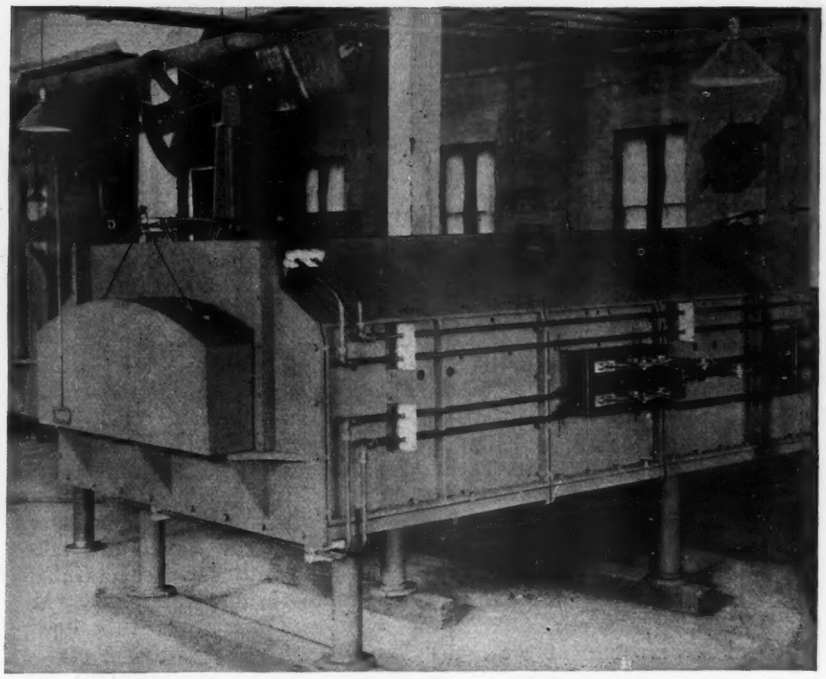
One of the first questions asked by those who are not familiar with electric heating and its many advantages is: "What is the cost of operation?" You must not forget in asking this question that the cost per unit of product is where the electric heater excels, not the cost per b.t.u. of heat. The cost per electric b.t.u. may be greater, but this is entirely outweighed by the savings to be effected by a better distribution of heat, automatic temperature control, reduction in maintenance, elimination of objectionable gases and fumes, reduction of fire hazards, the ease with which heating units may be adapted to conveying mechanism, and the like. However, even the cost of gas and oil fuel itself is not so much less, especially at the efficiencies which can be obtained in practice.

The efficiency of a high-grade gas oven with burners properly adjusted, and kept in that condition, will be approximately 80 per cent. However, due to the fact that the burners do not stay in adjustment and the adjustment must be made by an expert, the efficiency decreases to a considerable extent. A conservative efficiency might be considered as 60 per cent for an oven that has been in operation one year or more. The expenditure for artificial gas at efficiencies 30 per cent and below is quite large, which accounts for fuel oil being substituted for heat treating furnaces, which necessarily operate at these lower values.





This electric heat-treating oven averaged 10 lb. of metal treated per hour throughout the year. It operates at 1560 deg. F., treating leaf springs of automobiles. The oven is rated at 120 kw.



It is difficult enough to attempt to control the temperature of a gas-fired oven, but when it comes to an oil-fired oven, control is out of the question. Gas burners can be distributed so as to give approximately uniform heating conditions, provided temperature indicators are placed throughout the oven and an attendant is constantly on hand to manipulate the valves to hold the temperature at the desired point. With oil burners, the heat is concentrated at a few points; so that regardless of manipulation oil does not lend itself readily to the heating of large areas at low temperatures. Therefore, the field of oil fuel (both on account of the excessive cost of gas and the more favorable operating conditions) is in furnace work where the heat is confined to a small space and the temperatures are 1000 deg. F. and above.

The efficiency of a fuel-oil furnace depends upon its operating temperature primarily, and its construction secondarily. Since the hot gases must be at a higher temperature than the maximum temperature of the work to be heated, in order to impart heat to the work, it is evident that these gases must leave the furnace at a very high temperature. Also, since a large amount of air must necessarily be supplied to the flame in order to secure combustion, it is evident that the resulting heat loss is quite large, increasing as the operating temperature of the furnace increases. The quantity of air is so large that compressed air must be supplied in order to get a sufficient amount of oxygen in the combustion chamber.

Keeping in mind the efficiencies given, it is easy to see that although the actual cost per b.t.u., as shown in Tables 1 and 2, may sometimes be greater for electric heat, the cost per equal amount of useful heat is not necessarily higher. In these tables it is assumed that all the electric heat is used giving 100 per cent efficiency, or 3412 b.t.u. per kw.-hr. A cubic foot of gas is assumed to contain 600 b.t.u. and a pound of oil 18,000 b.t.u.

TABLE 1—This is how the energy cost (only) of gas compares with electricity for heating ovens

Electrical energy is taken as 1 cent per kw.-hr. and gas at $1 per 1000 cu. ft. The gas has 600 B.t.u. per cu. ft., and one kw.-hr. is equivalent to 3412 B.t.u.

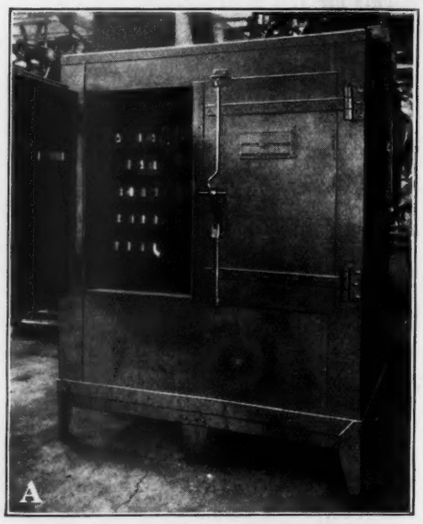
Electrical Energy	Artificial Gas		
Cost per 100 Kw.-Hr.	Efficiency of Oven, Per Cent	Cu. Ft. Gas equal to 100 Kw.-Hr.	Cost of Gas equal to 100 Kw.-Hr.
$1.00	100	570	$0.57
1.00	90	634	0.63
1.00	80	713	0.71
1.00	70	815	0.82
1.00	60	950	0.95
1.00	50	1140	1.14
1.00	40	1425	1.43
1.00	30	1900	1.90

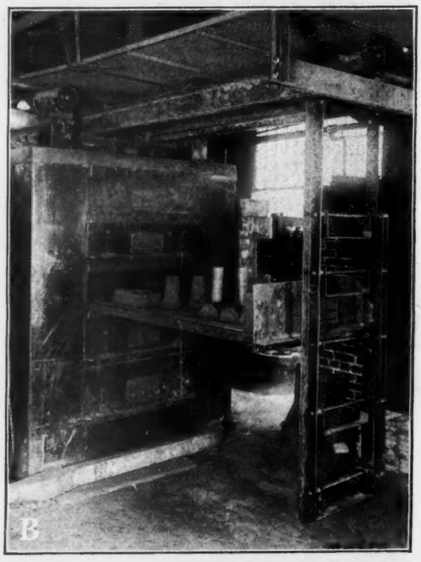
TABLE 2—See how electric energy and oil-fuel compare for heating ovens

Cost of electrical energy taken as 1 cent per kw.-hr. One kw.-hr. is equivalent to 3412 B.t.u. Cost of oil is 1 cent per lb. and the oil contains 18,000 B.t.u. per lb.

Electrical Energy	Oil			
Cost per 100-Kw.-Hr.	Oven Temperature deg. F.	Efficiency of Ovens Per Cent	Lb. Oil equal to 100 Kw.-Hr.	Cost of Oil equal to 100 Kw-Hr.
$1.00	....	100	18.9	$0.19
1.00	....	80	23.7	0.23
1.00	....	50	37.9	0.38
1.00	1000	30	63	0.63
1.00	1200	20	95	0.95
1.00	1400	15	126	1.26
1.00	1600	12	158	1.58
1.00	1800	10	189	1.89
1.00	2000	8.5	223	2.23
1.00	2200	7.5	253	2.53
1.00	2400	7	271	2.71

Some Uses of Electric Ovens *in Industrial Plants*


A


B

A—Castings are aged in this electric oven at the plant of the Wills-St. Clair Company, Marysville, Mich.

B—This electric oven helps the molder to make more and better castings, by baking the cores properly.

C—This conveyor oven bakes light metal stampings quickly and cheaply in the plant of the Patent Novelty Company, Fulton, Ill.

D—Automobile bodies are baked in this nine-compartment oven in the plant of the Chevrolet Motor Company, Tarrytown, N. Y.

E—In heat-treating steel the uniformity of heating and close temperature control of the electrically heated furnace have reduced to a minimum the rejections due to imperfect work.

F—Here is a multiple-pass oven which japans and bakes small parts at low cost.

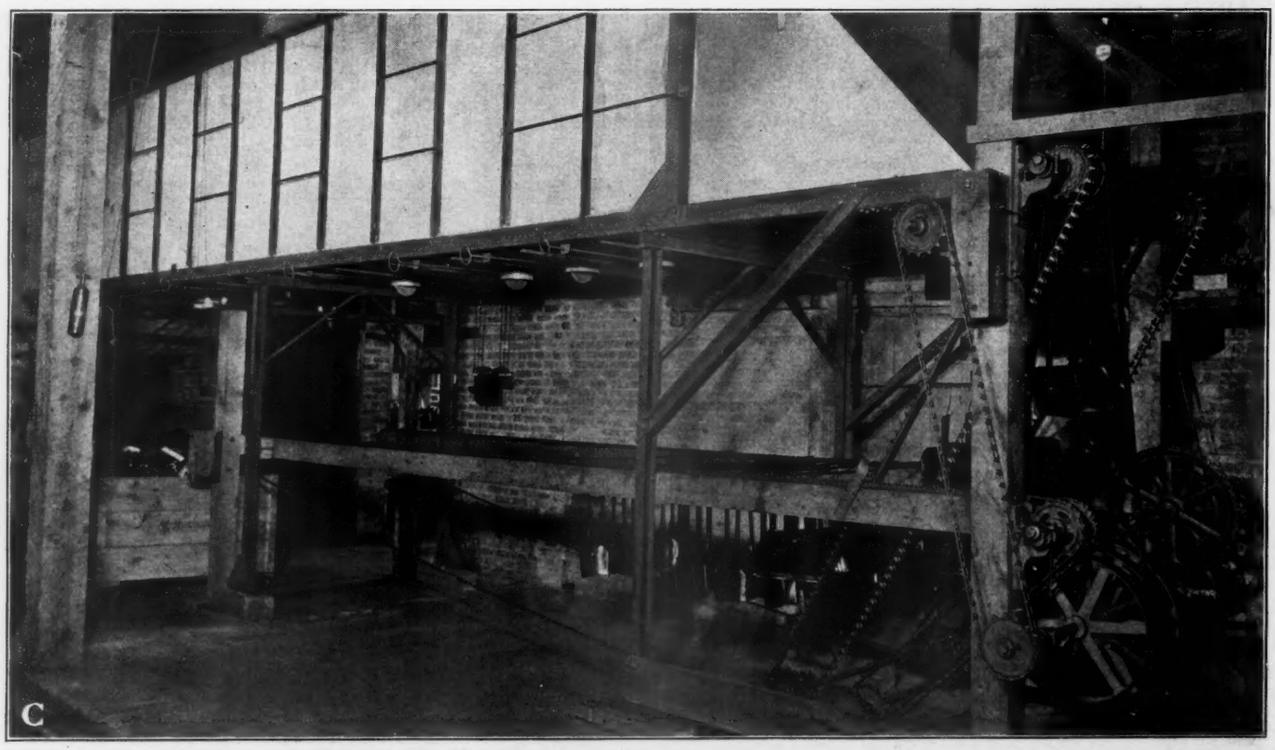
G—This small oven is used for drying materials and parts and baking japan. Automatic control keeps the temperature at the desired point.

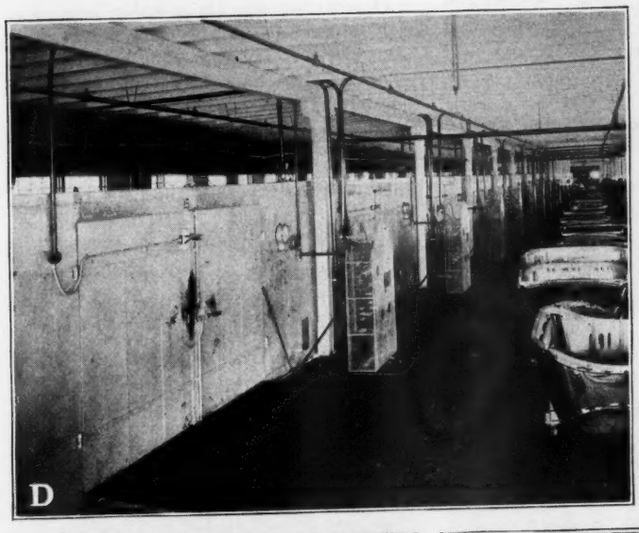
H—Because armatures can be baked carefully and uniformly, electric ovens are used in the shops of the Brooklyn Rapid Transit Company, Brooklyn, N. Y.

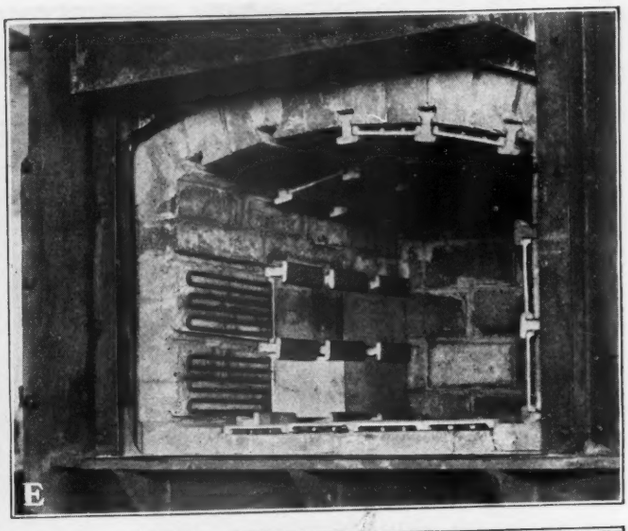
I—The trays of parts, supported on carriers which run on an I-beam, are pushed into the oven at one end and when baked are taken out at the other end. The Gabriel Manufacturing Company, Milwaukee, Wis., uses this equipment.

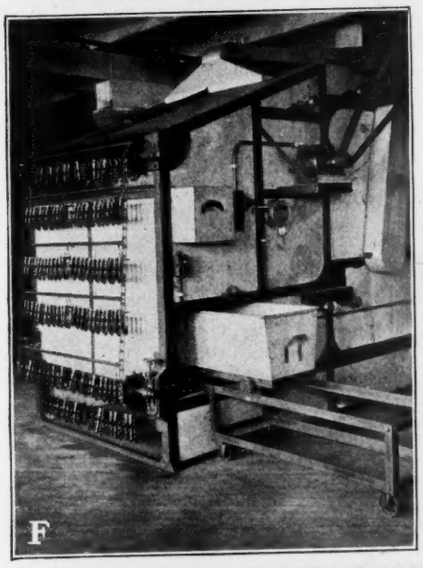
J—This is a two-compartment oven, arranged for loading by truck or overhead trolley, installed in the plant of the Mueller Furnace Company, Milwaukee, Wis.

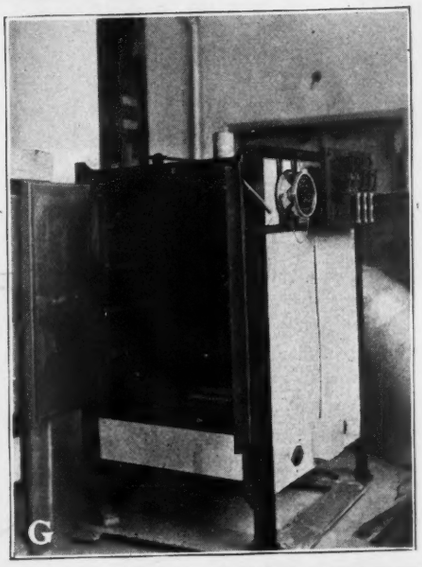
The ovens shown at A, B, D and I were manufactured by Young Brothers Company, Detroit, Mich.; those at C, F and J by the Paul Maehler Company, Chicago, Ill.; those at E and G by the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., and the one at H, by the Oven Equipment and Manufacturing Company, New Haven, Conn.

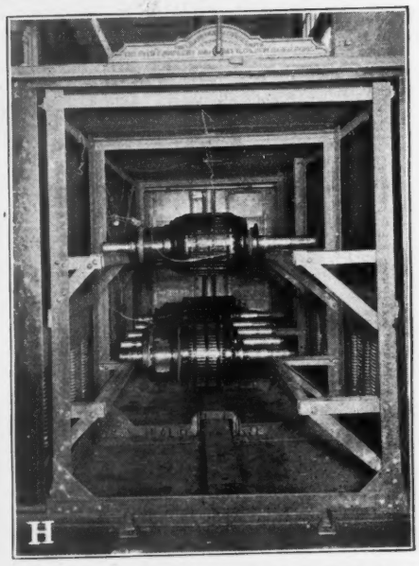

C

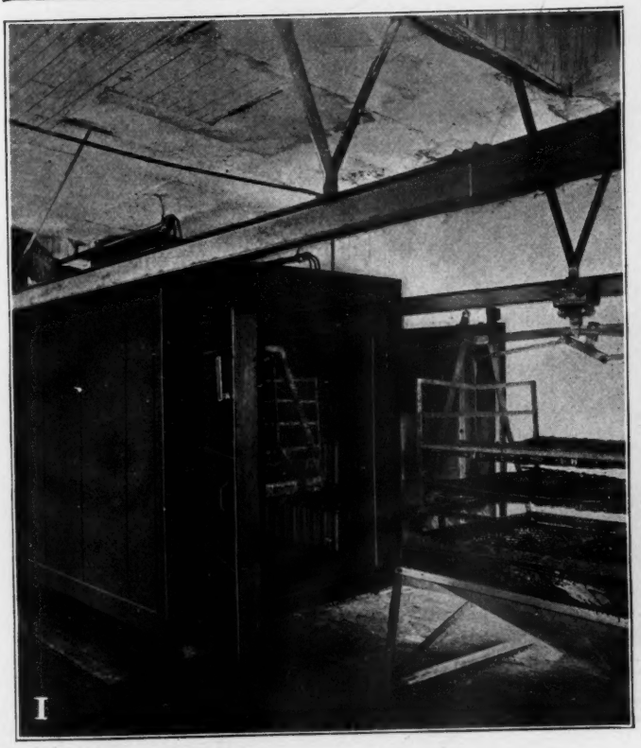

D

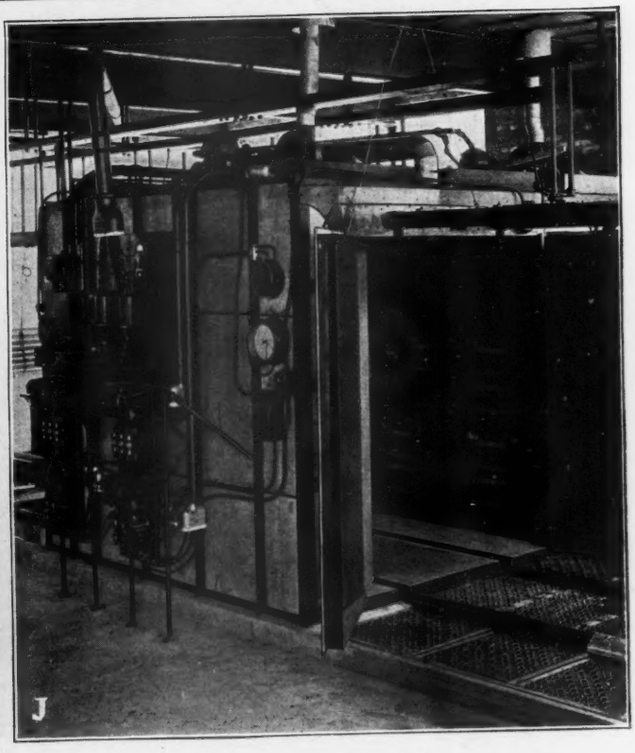

E

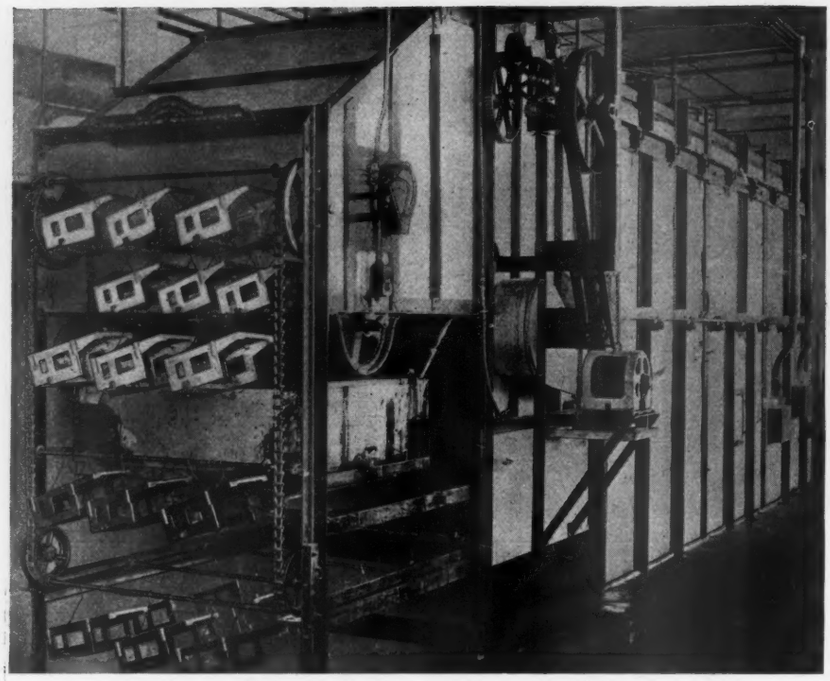

F


G


H


I


J



This automatic electrically heated oven handles small parts, such as typewriter frames, fans, automobile license tags, and the like. It delivers them enameled and baked.

Amount of Ventilation Necessary for Baking Enamel

In up-to-date enameling ovens, the ventilation is accurately controlled by means of motor-driven exhaust fans expelling a definite amount of air from the oven each minute. Until quite recently it was common practice to figure on supplying a certain number of changes of air per hour in terms of the cubical contents of the oven, from 15 to 20 changes being the most commonly specified.

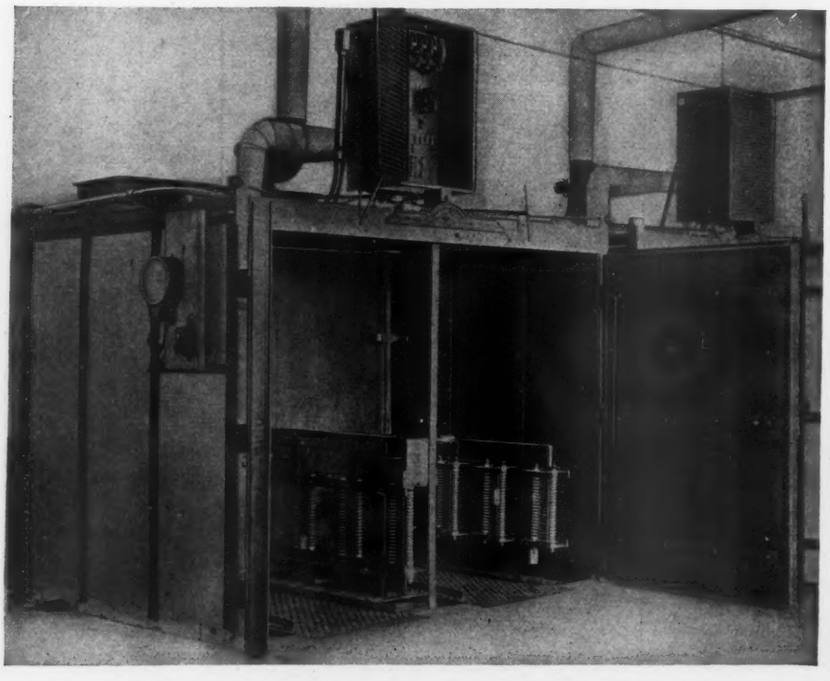
However, this method was inaccurate, since the amount of ventilation needed depends directly upon the amount and kind of solvent used per bake and could only be very roughly approximated in terms of oven capacity. The actual amount of solvent in the oven depends upon the exposed surface of the enameled parts being baked.

In large installations where the power required for heating the air assumes large proportions, it was necessary to determine definitely the amount of ventilation required. In order to carry out such experiments, an electrically heated cylindrical oven was constructed, the heating elements being wound around the external surface of the oven. The capacity was 1,550 cubic centimeters. In view of the fact that in any commercial oven there is always the possibility of an arc occurring either in the heaters or connectors, sufficient ventilation must be maintained at all times so that if an arc should occur the mixture of volatile vapors and air will be sufficiently lean not to take fire or explode. To determine such conditions, a spark plug was placed in the oven and connected so as to produce a very intense arc.

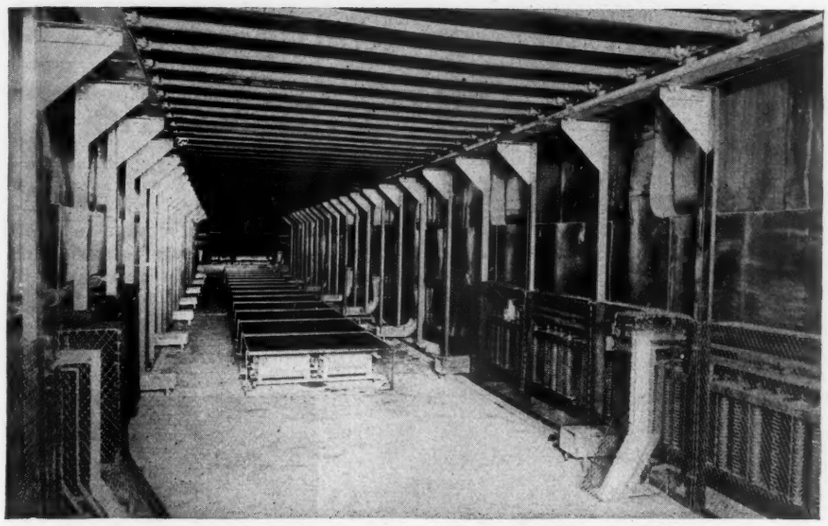
In working out experiments in this oven samples of enamel were obtained and an analysis made as to the amount and kind of solvent present. In one specific case, where samples were submitted for three-coat work, the solvent was a turpentine substitute of 0.786 specific gravity with a distillation range from 150 to 220 deg. C. The amount of solvent in the enamel, by weight, was: initial primer, 41.28 per cent; rubber first coat, 54.50 per cent, and finish enamel, 45.00 per cent.

Experiments were then made with different percentages of enamel to determine the *lowest* percentage of solvent vapor mixed with air which would cause a mixture that would be explosive.

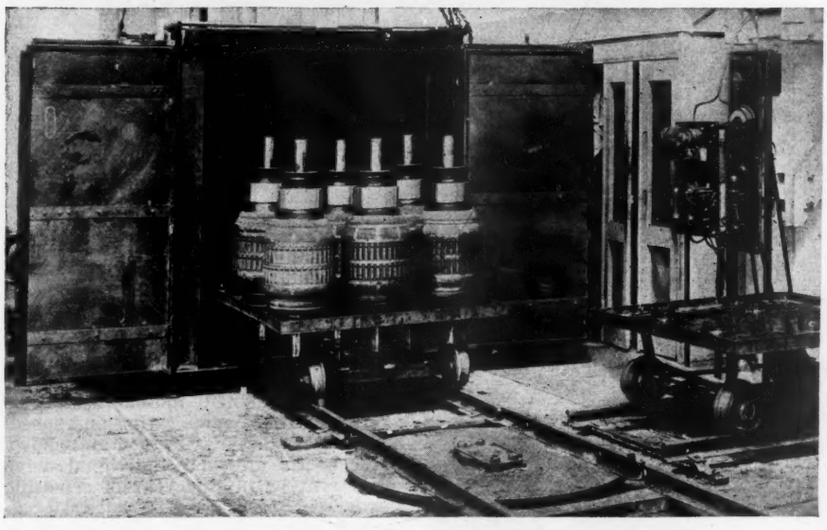
It was found that a mixture of 92 per cent air and 8 per cent solvent vapor (both percentages by weight) would cause an explosion. A mixture of 93 per cent air and 7 per cent solvent would take fire, but not explode. A mixture of 94 per cent air and 6 per cent solvent would not take fire. Allowing for an ample factor of safety, a mixture of 95 per cent air and 5 per cent solvent was recommended. As the percentage of solvent vapor increased, the explosions increased in violence, until they became very forceful with 85 per cent air and 15 per cent solvent. Increasing the solvent vapor beyond this point, the explosions became less violent due to a resultant



The control panels and the exhaust fans are on the roof of this oven, but the exhaust pipes draw the air from the bottom of the oven where the fumes from the enamel gather.



Large automobile parts to be enameled travel through this oven hung from the rods at the top at a speed of 2 ft. per minute. Note the vent pipes extending out into the oven at the floor line 12 ft. apart. This oven is 120 ft. long, 12 ft. wide and 8 ft. high. Its rating is 400 kw. Electric heat excels in the baking of armatures. Below an oven is shown that is used for baking electric railway armatures.



rich mixture, but it was found that in such cases, the amount of oxygen present in the air was not sufficient to oxidize the enamel in a satisfactory way.

A review of the foregoing data on the development in the automobile industry brings out the necessity for a power engineer handling this work to know thoroughly the apparatus with which he is working, and know the application as well as all the operations affecting the cost of pieces to be baked or to be heat-treated.

Operating Costs of Heat-Treating Furnaces

In working up a heat-treating problem, the difficulty confronting an engineer in determining the operating costs is lack of data regarding the heating characteristics which affect these costs. The weight and kind of material to be heated is usually known, as is also the operating temperature, but unless the engineer knows the kilowatt hours required for heating up the furnace from cold, and the kilowatt hours required to maintain the furnace at a definite temperature (radiation losses), he must estimate the values as closely as possible. In order to supply this want, exhaustive tests have been made and the data shown in Table 3 has been obtained.

Although this table shows a range up to 1800 deg. F., it is of interest to note that electric furnaces are now on the market of any size and capacity required, for temperatures up to 2000 deg. F.

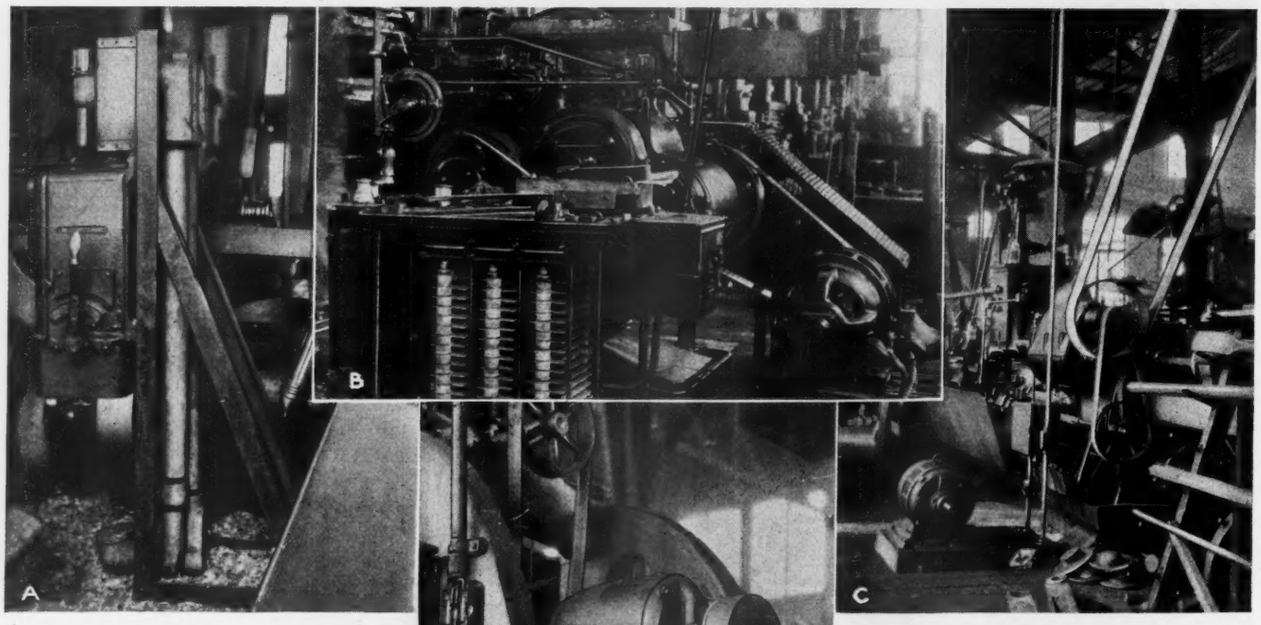
TABLE 3—Kilowatt-hours required by electric heat-treating furnaces to raise temperature of cold furnace and to hold at different temperatures

Style of Furnace	Inside Dimensions, Inches			Kw. Full Load	Raising to 1,800 deg. F. from Room Temp.		Kw.-Hr. per Hour holding at deg. F. shown		
	Width	Length	Height		Time Hr.	Kw.-Hr.	1400	1600	1800
Single-End	18	24	13½	22.66	3.33	75.5	3.8	4.5	6.2
" "	18	36	13½	29.88	3.25	97.1	4.3	5.7	7.4
" "	18	48	13½	40.60	3.25	131.9	4.7	6.1	8.2
" "	18	72	13½	57.75	3.25	187.7	6.4	8.2	11.0
" "	25	36	16	35.86	3.33	119.5	5.1	6.7	8.5
" "	25	48	16	48.72	3.33	162.4	6.4	7.9	10.4
" "	25	72	16	69.30	3.33	231.0	8.5	10.3	13.8
" "	32	48	16	56.84	3.25	184.7	7.4	8.6	10.8
" "	32	72	16	80.85	3.25	262.8	9.9	11.7	5.1
Double-End	18	72	13½	57.75	3.33	192.5	7.4	10.4	13.7
" "	25	72	16	69.30	3.50	242.5	10.0	12.0	15.7
" "	32	72	16	80.85	3.66	296.5	11.7	13.8	17.8

Some Revamped Motor Drives in the Railroad Shops at Portland, Maine

HERE are some examples of motor drives and applications of control apparatus which have been worked out by Asa Martin, electrical engineer of the Portland shops of the Maine Central Railroad, which are supplied with power by the Cumberland County Power & Light Company. The letters of the following paragraphs refer to the letters in the lower left-hand corner of each of the accompanying illustrations.

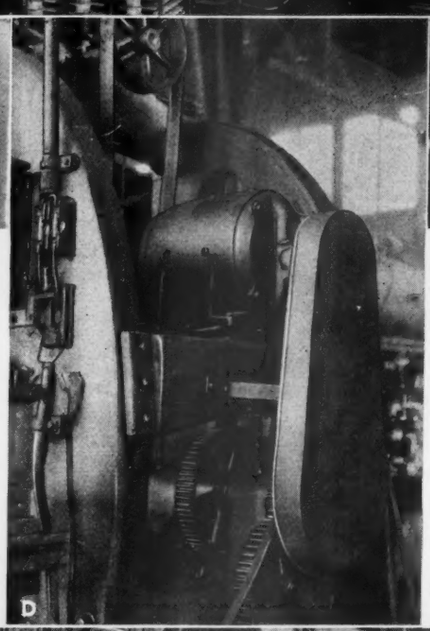
A.—This starter was installed in such a way as to give maximum freedom from interference with shop processes and to insure operation without injury of equipment from external causes. In this case a 60-hp. motor starter with overload relay equipment is mounted on a frame of 1½-in. angle-iron, braced at the rear and fastened to the floor of the wood mill. The 440-volt leads to starter and motor are in 2-in. rigid conduit.

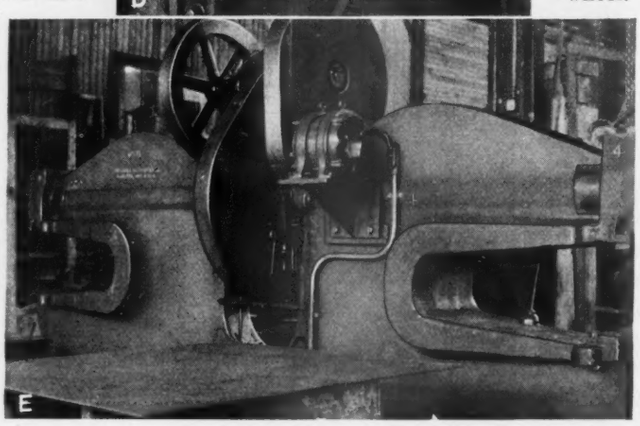


B.—This illustration shows a variable speed, 15-hp., 440-volt motor driving a Morton shaper. At the left is a combination oil circuit-breaker, controller and resistance units mounted in a unit structure of pipe frame. These resistors are to be inclosed when the installation is completed. A recessed top of the frame provides a handy table for hand tools.

C.—A turret lathe is shown here undergoing a transformation from belt drive and overhead shafting to individual motor drive. A motor on the floor at the rear of the lathe and belt connected to its pulley will handle this service. The chief advantages of the new arrangement are convenience in operating the lathe independently of the line shaft and the localization of control resulting from the individual drive.

D.—Here is a motor-driven boring mill which has been in service about fifteen years. It is interesting as an early example of motor-tool application. The motor is mounted on a bracket carried between the frame pieces. A direct belt drive is inclosed in the guard which was added after the original installation was made. This drive provides flexibility enough for good service and except that a more recently designed motor would be smaller for the same rating and speed, the installation is still good and shows how useful an early individual drive may still be in this year of scientific progress, 1922.





E.—This is a good example of the compactness of a motor drive designed for service on a heavy machine tool. A Long & Allstater combination punch and shear is direct-driven by a 3-hp., 440-volt motor, equipped with flywheel. This unit amounts to two tools in one with a single motor drive from a simple right-angled bracket on the frame at one side with rigid conduit feed and behind, out of sight, a motor switch convenient for the operator. The punch will perforate a ¾-in. plate with a ¾-in. hole and shear a 3-in. by 3-in. by ¼-in. angle. Treadle control operates the punch and shear. Note the safeguarded gear drive and mechanical balance of this installation. The motor must be able to handle sudden shifts from no load to momentary full load on both punch and shear.

WHEN WINDING COILS for motors care must be taken to make them up in such a way that they will be durable, and easy to insert. These qualities are determined by the shape of the coils, the method of winding, the size of wire, the insulation and a few other things which will be mentioned in this article. Among the coils for which winding data are given are mush, threaded-in diamond puller, insulated puller, mold-wound and strap-copper coils. This is the fifth of a series of articles on motor repair by Mr. Roe, who is shop superintendent of the Detroit Service Department of the Westinghouse Electric & Manufacturing Company.

A. C. ROE Shows How to Make Up

Diagrams For Coil Winders

With Information Needed When Using Different Types of Coils

BEFORE starting to wind a set of coils, the necessary information should be written down, so that it will be convenient for use by the coil winder. This information may be obtained from an old coil taken from the machine or it may be determined by making measurements on the slots, etc., as explained in the ELECTRICAL REVIEW AND INDUSTRIAL ENGINEER for April, page 159. This information will be of value also when it is decided to substitute a less expensive coil in the new winding for the old kind of coil. The best kinds of coils to use for different types of slots, size of wire, voltage, etc., are shown in Table I. Table II gives in condensed form the directions for making various kinds of coils. It tells the different operations in winding, insulating, dipping, etc., and gives the time required. It covers mush, mush-puller, threaded-puller, mold-wound, bipolar, insulated puller and strap-copper coils. This table should be posted in the coil-winding shop and a copy should be in the hands of the man who is figuring on the coils before winding.

Some systematic plan should be followed in recording this information and presenting it to the winder. A very effective system employed by the writer makes use of 4-in. by 6-in. cards such as shown in Fig. 1.

All the instructions for a set of coils are placed on one small card. This card is passed successively to the carpenter who makes the mold or the shuttle, to the winder and to the coil puller and taper, etc. In developing the cards the coil records of a large shop for two years were studied, with the result that a few symbols and instructions were chosen to cover virtually all types of coils. The arrangement of the card and the wording were carefully thought out to make it apply to all types of coils. The back of the card is used for coil dimensions shown diagrammatically. The top line on the face of the card is reserved for the order number and the name of the customer to whom time and material are charged. The next three lines may be used, if desired, for such data as type of motor, horsepower, voltage, serial and style numbers, etc., but as each motor repaired receives a separate order number, the nameplate data are not necessary for this card. It is a simple matter to find such data in a file in which a 6-in. by 8-in. card is kept for each customer.

On the fourth line of the card, MLD (mold) is printed to give the mold number on which the coils are to be made. This number is entered only when it is necessary to make

Table I—Kinds of Coils to Use for Different Types of Slots and Windings

Type of Slot	Size of Wire	Type of Winding*	Type of Coil to Use: Up to 220 Volts	Type of Coil to Use: 440 and 550 Volts
Open	No. 15 and smaller	Two-layer diamond, staggered (in-and-out) bipolar	Bip	P-C-B
	No. 14 and larger	Two-layer diamond	P-C-A or C-W	P-C-E
	Any size	Scant end room, as in involute, half-diamond, half-involute and other special windings	Mld-A	Mld-B
	Strap	Two-layer diamond, involute, etc.	Ren-A	Ren-B
Partly Closed	Any size	Concentric, concentric-chain, (for two-pole polyphase, or for single-phase stators)	C-M†	C-M
	No. 15 and smaller	Two-layer diamond, basket, two-layer diamond with one coil per slot	M	M
	No. 14 and larger	‡ Two-layer diamond, basket, two-layer diamond with one coil per slot	M-P or Bip-B	T-P
	Strap	Two-layer diamond, involute, etc.	Ren-C	Ren-C

* For voltages higher than 550 to 600 use "H" insulation: i.e., P-C-H, Mld-H, etc., coils. Do not wind any M, M-P, Bip, or C-M coils with square or ribbon wire.
† When winding reduce the crossing of wires to a minimum.
‡ With wire as large as No. 14 it is advisable to change basket, and two-layer-one-coil-per-slot windings to two-layer-two-coils-per-slot diamond windings, M-P or T-P

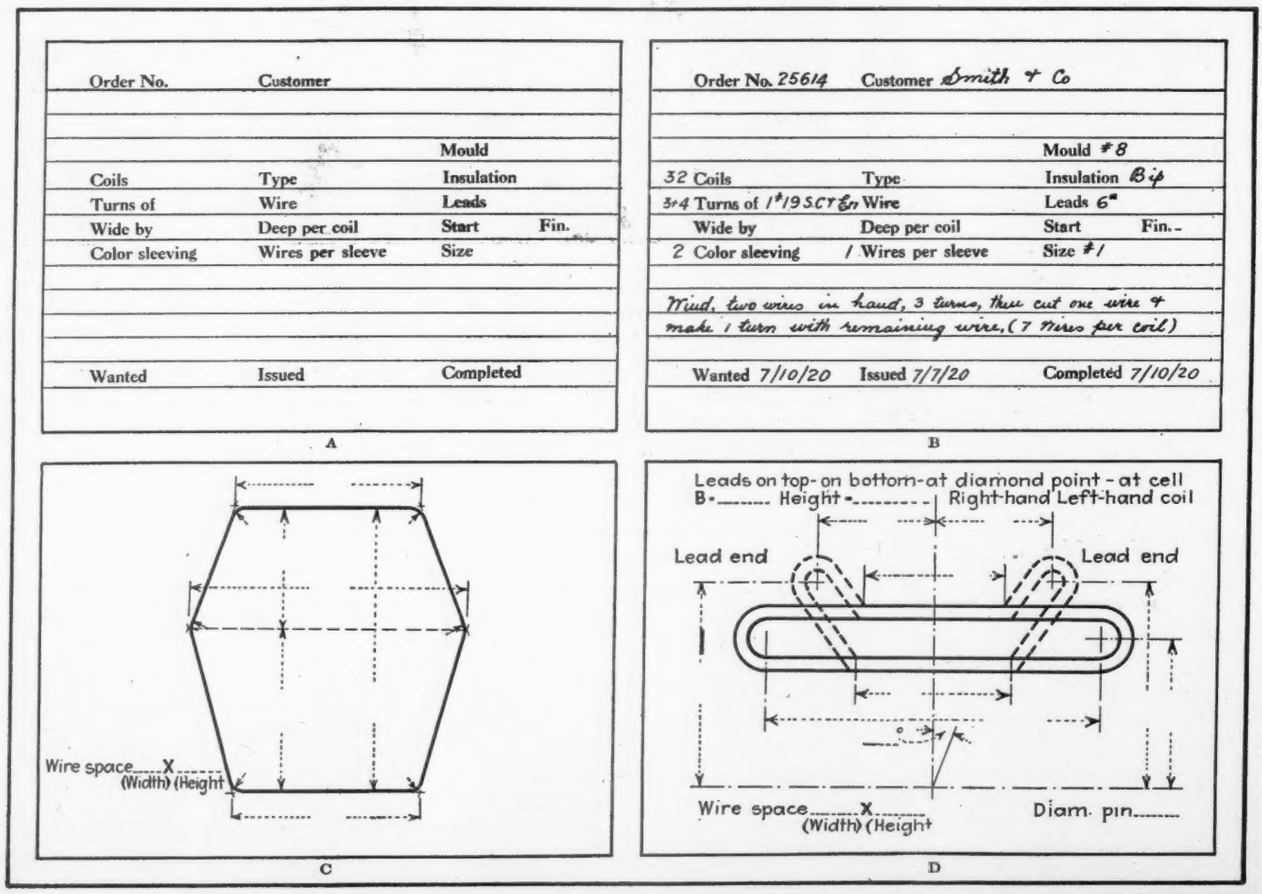
a mold valuable enough to warrant storing.

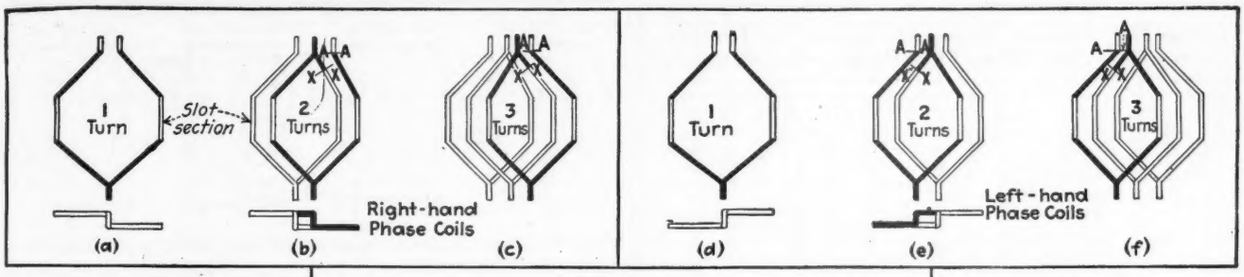
On line 5 of the card are entered the number of coils, type and insulation. In entering the last item, certain symbols are used to designate certain types of coils. These symbols, with their meanings, are given in Table II.

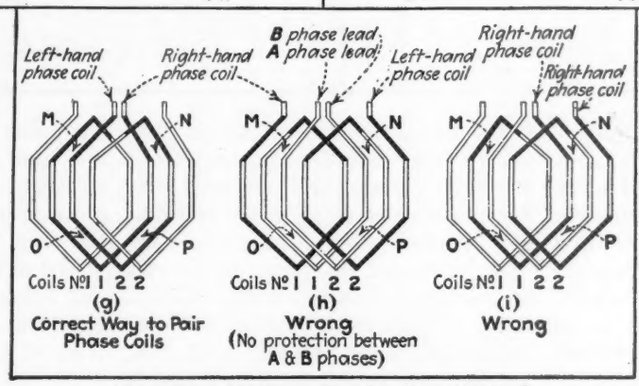
Tables III to VI, inclusive, show sizes of various kinds of wire, round, square, strap and ribbon. Table III gives the linear space occupied by different numbers of cotton-covered wire. When the size of wire is changed, a table is useful showing how many wires of one size are required to replace a certain number of another size. For instance, suppose two No. 10 wires may be replaced by wires of other sizes. To find how many No. 14 wires should be used in place of two No. 10, trace down from 10 in the top line to figure 2. Then follow to the left until under 14 is found figure 5. This means that five No. 14 wires may be substituted. Similarly, four No. 13 might be used, or one No. 7, depending upon the slot space and the formation of the wire in the slot.

In making out the card, the size and kind of wire, the turns per coil, and the length of leads are shown on line 6. The seventh line is used for the arrangement of the wires in the coil, i. e., number of wires wide by number of wires deep. This line is not filled out for mush coils. At the

Fig. 1.—How information for making coils can be entered on a 4-in. x 6-in. card.
These cards are used for all types of coils. *A* is the face of card and diagrams *C* and *D* are on reverse sides. *B* is the form filled out for a special mush coil. This shows how the blank lines at the bottom of the card are used. A mush-coil diagram (*C*) is on the reverse side. The diagram (*D*) is used for puller coils.







How Phase Coils are Insulated and Paired

The nine figures, *a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*, *i*, illustrate how phase coils are insulated and paired for induction motors wound with strap-copper coils and having partly closed slots into which the coils are threaded, one conductor at a time. First, the total number of phase coils required is found by the formula: P. C. = 2 × number of poles × number of phases. For instance, a four-pole, three-phase motor would have 2 × 4 × 3 = 24 phase coils. Then the total number of phase coils are divided into two equal piles, one pile being called left-hand phase coils and the other pile being called right-hand phase coils.

The first right-hand turn for right-hand phase coils (with leads away from you) as *AA* to *XX* in drawings (*b*) and (*c*) should be taped with one-half-lapped layer of Empire tape (0.008 in. thick), this tape being applied to the section of coil that is shown dark in the drawings; *i.e.*, the end parts of the coil (from wrapper to wrapper). Then one layer of red cotton tape is applied over the Empire tape, the red tape being wrapped also over the insulating cell on the slot section of the coil. Red tape starts at *AA* and ends at *XX*, from which point one layer of white tape is applied, the manner of lapping depending upon the insulation desired. The left-hand phase coils are taped in the same manner except that the taping starts on the left-hand turn of the coil as shown as in the drawings *d*, *e* and *f*.

The correct method of pairing phase coils is shown in drawing *g*. Two incorrect methods are shown in *h* and *i*. First, a left-hand phase coil and a right-hand phase coil must be paired together. The extra-insulated leads for both coils (those leads with the red tape) must be placed adjacent to each other as in Fig. *g*. When the coils are placed in this position the end portions of the coils which are adjacent, as *M*, *N*, *O* and *P* in Fig. *g*, are doubly insulated from each other.

When a right-hand and a left-hand phase coil are paired together, as shown in Fig. *h*, there is no extra protection between the adjacent end portions of the coils, as in *M*, *N*, *O* and *P*, in Fig. *h*. This method of connection is accordingly incorrect. Likewise, it is wrong to connect two right-hand or two left-hand phase coils together as in Fig. *i*. In this case only half the insulation required is present between the end portions of the coils as illustrated at *M*, *N*, *O* and *P*, in Fig. *i*.

Table II—Symbols for Different Types of Coils with Operations and Time Required

Symbol	Manufacturing Information	Operations Involved	Days*
M	(Mush). Coils wound hit-and-miss, *i.e.*, not wound in layers.....	Make mold, wind....	1–2
M-P	(Mush pullers). Coils mush-wound on shuttle and pulled to final shape. Starting and finishing leads sleeved while winding and tied in place when pulling with two turns of light flax cord; knot tied on top, four cord bands per coil, two at each end, one inch either side of the diamond point.	Make shuttle and puller blocks, wind pull.....	1–3
C-M	Same as M, except C-M coils require more than one mold.....	.....	1–4
T-P	(Threaded puller). Wire-wound coils, for partially closed slots, the coils being wound in layers on a shuttle and pulled to final shape. Starting lead only is taped with 0.004-in. x ¾-in. cotton tape, while winding. When pulling, the lead end of coil is taped around the diamond point and one inch either side with 0.007x¾-in. cotton tape, half over-lapped. The coil leads are not caught under this tape, but are tied down with cord bands consisting of $\frac{1}{16}$-in. diameter cord, twelve turns per band, four bands per coil, two at each end. Coils are dipped in thin plastic varnish before pulling.	Make shuttles and blocks, wind, pull, dip, bake.....	1–5
Mld-A	(Mold A). Coils wound to final shape on a mold for 110-volt to 220-volt open-slot A.C. and D.C. machines. All leads sleeved while winding, and a thin paper cell glued in place on slot section of coil to hold it rigid. The required number of single coils are then assembled (with glue between) to make a whole coil, then hot-pressed, a one-and-a-half turn treated-cloth wrapper is applied on slot section, and the coil is then taped all round with 0.007x¾-in. cotton tape half-lapped on ends and spaced on wrapper. Phase coils same as for P-C-A.	Make mold, wind, assemble, press, dip in plastic varnish, wrap, dip in varnish, tin leads	3–6
Mld-B	(Mold B). Same as Mld-A, except for 440 volts and 550 volts. Insulate as per P-C-B.....	See Mld-A.....	3–6
Mld-H	(Mold H). Same as Mld-A, except for 1,000 volts and 2,300 volts. Insulate as per P-C-H.....	See Mld-A.....	3–9
Bip	(Bipolar). Coils wound flat mush, for open-slot machines. Leads sleeved while winding, coils taped with 0.004-in. x ¾-in. cotton tape, half-lapped all round (semi-tight), coils not dipped.	Mold, wind, tape.....	1–3
Bip-B	(Bipolar B). Same as Bip, except that coils are taped on ends only, *i.e.*, from slot section to slot section.	See Bip.....	1–3
C-W	Diamond-point pulled coils, which are wound in layers on a shuttle, sleeved while winding, pulled to shape, then taped all round with 0.007-in. x ¾-in. cotton tape, half-lapped (holding wires square and even while taping). Dip once after taping in plastic varnish.	Make shuttle and blocks, wind, pull, tape, dip.....	2–5

*Days required to make a set of coils (minimum and maximum).

Symbol	Manufacturing Information	Operations Involved	Days*
P-C-A	(Puller coil A). Wire-wound and insulated coils for open-slots, 110 to 220 volts. A.C. and D.C. Coils are wound in layers on a shuttle, starting and finishing leads sleeved, slot section of coil held rigid by shellacked strips or paper cells; pulled to shape, leads tied, dipped in plastic varnish. While taping a one-and-a half turn treated-cloth wrapper is applied on slot sections and whole coil is taped with 0.007-in. x ¾-in. cotton tape, half overlapped on ends and spaced on the wrapper. For A. C. machines the phase coils are reinforced with one layer of 0.008-in. x ¾-in. bias treated-cloth tape, half overlapped on each end, sealing the ends of wrapper and extending from wrapper to wrapper. The phase coils are painted red at the lead end, or longer leads used to distinguish these coils.	Make shuttles and blocks, place strips or cells, pull, dip in plastic varnish, tape, dip in clear varnish, tin leads..	3–6
P-C-B	(Puller coil B). Same as P-C-A, except that it applies to 440-550-volt A.C. and D.C. machines and that a one-and-a-half turn mica and fishpaper wrapper is used, instead of treated cloth.	See P-C-A.....	3–6
P-C-H	(Puller coil H). Same as P-C-B, except that it applies to 1,000 to 2,300-volt A. C. machines. A two-and-a-half-turn mica and fishpaper wrapper is used for 1,000 volts to 1,110 volts, and for 1,100 volts to 2,300 volts a three-and-a-half-turn mica and fishpaper wrapper is used, and all coils (1,000-2,300) are reinforced on ends with one layer of 0.008-in. x ¾-in. bias treated-cloth tape half-lapped, the phase coils having two layers of treated-cloth tape with varnish brushed on between layers and all coils dipped three times in a clear varnish. After taping coils are sandpapered between dips to give a smooth and glossy finish.	See P-C-A.....	3–9
Ren-A	(Reinsulate A). Reinsulating strap-copper coils for A.C. and D.C. 110-volt to 220-volt open-slot machines, having one to five straps per coil. Tape odd-numbered straps, on ends only (part outside of slot section), with one layer of 0.007-in. x ¾-in. cotton tape, half-lapped; extend this tape ¾ in. onto slot section of coil and dip coils in plastic varnish. Then use a one-and-a-half-turn mica and fishpaper wrapper, interwoven between straps, on slot section; tape with 0.007-in. x ¾-in. cotton tape, half-lapped on ends and spaced on wrapper. When phase coils same as P-C-A are required, dip coils in clear varnish; otherwise dip coils in plastic varnish.	Clean, tin leads, reform, assemble, dip, wrap, dip, tin or clean leads.....	1–14
Ren-B	(Reinsulate B). Strap-copper coils for 440-volt and 550-volt open-slot machines, same as Ren-A, except tape all straps on ends and use a two-and-a-half-turn mica wrapper.	See Ren-A.....	1–14
Ren-C	(Reinsulate C). Strap-copper coils for threaded-in (partly-closed-slot) machines. Each strap should have a one-and-a-half-turn mica and fishpaper wrapper on the slot section; *i.e.*, a two-turn coil would have four wrappers and a three-turn coil six. The coil is taped with one layer of 0.004-in. x ¾-in. cotton tape, half-lapped on ends and spaced on cell part. Phase coils should be half rights and half lefts, see Figs. a, b, c, d, e, f, g, h, i (above), which show how the phase coils are insulated and assembled.	.....	1–14

Table III—Linear Space Occupied by Double-Cotton-Covered Wires Laid Side by Side (Inches)

No. of Wires	Wire Size, B. & S. Gage Number														
	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1																
2																
3																
4																
5																
6																
7																
8																
9																
10																
11																
12																

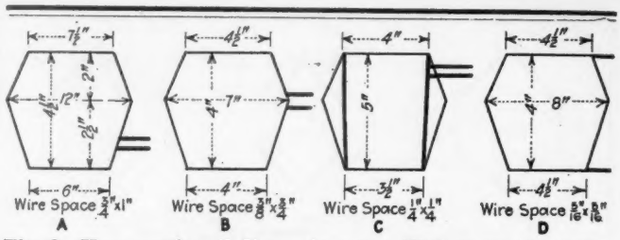


Fig. 2—How mush-coil dimensions are filled in on diagrams. Note that the position of the leads is indicated by heavy lines. *A* is a basket mush coil. *C* and *D* are bi-polar coils. In *C* two vertical lines have been added, showing that the coil ends are straight instead of diamond-pointed. This is the diagram in *C* of Fig. 1.

end of the seventh line are the expressions "Start" and "Fin.," signifying "start" and "finish," which are used only when one lead must be longer than the other. The words "start" and "finish" are used in preference to "top" and "bottom," as the average coil winder would not know the top lead from the bottom but would understand what lengths of wire to leave outside the mold when starting and finishing the coil. It is the duty of the person making out the order to apply these terms to the proper leads.

For determining the correct size of sleeving for the leads, a sample sleeving card is helpful. A snug fit should be chosen. Although a large sleeve will slide on the wire easily, too large a sleeve will make a baggy appearance after it has been dipped in paint.

Line 8 on the card is used to denote the sleeving required. The size of sleeving, number of colors, and numbers of wires per sleeve should be specified. Any other information that is absolutely necessary can be added on the following lines. On line 13 are entered the date on which the coils are wanted, the date the order was issued and the date on which the job was completed. An example of a card which has been filled out is shown at *B*, Fig. 1. The use of the extra lines at the foot of the card is illustrated. These cards can be run off on a duplicating machine or can be printed at a small cost. Ruled cards may be used instead of printing the lines.

On the reverse side of the card are shown the coil dimensions. Only two forms of diagrams are used, one for mush coils (*C*, Fig. 1) and one for puller coils (*D*, Fig. 1). These are printed on the cards as desired by means of rubber stamps. If the work is done by a printer, the diagrams might be printed from cuts, or they may be put on from a sketch by a duplicating machine.

The method of filling out the diagram for mush coils is seen in Fig. 2. It will be seen that the position of the leads is indicated by the heavy lines added to the diagram. In *C* two vertical lines have been added, showing that the coil ends are straight instead of diamond-pointed. By such slight modification one diagram is applied to any mush coil.

Information on the puller coil is more complicated. In the diagram (*D*, Fig. 1) the notations "Leads on top," "on bottom," "at diamond point," "at cells" are used to indicate the position of the coil leads. The top of the coil is that part farthest from the shaft on a rotor and closest to the shaft on a stator (*d*, Fig. 3).

The terms *B* and *HT* in the next line refer to the width and height of the puller coil, shown at (*b*), Fig. 3. *RH* and *LH* mean right hand and left hand, respectively. One of these pairs of terms is crossed out when the card is being filled out.

The difference between right-hand and left-hand coils should be studied carefully. Using a left-hand coil in place of a right-hand in a direct-current, wave-wound armature would reverse the direction of rotation in a motor or the polarity in a generator, and would cause other troubles in compensated interpole machines. Fig. 4 shows a right-hand and a left-hand coil. To determine the kind of coil, hold it as it would fit in a rotor, with the leads toward the observer. If the high side (the side that would fall in the top of the slot) is to the right it is a right-hand coil (*A* in Fig. 4). The reverse holds for a left-hand coil (*B*, Fig. 4). When winding a right-hand coil in a shuttle, the groove for the starting lead should be on the left-hand side of the shuttle. For a left-hand coil the groove should be at the right.

At (*a*), Fig. 3, a puller-coil diagram is shown lettered to correspond with the cross-section of a motor at *d*. All dimensions are obtained from the motor and a sample coil. The

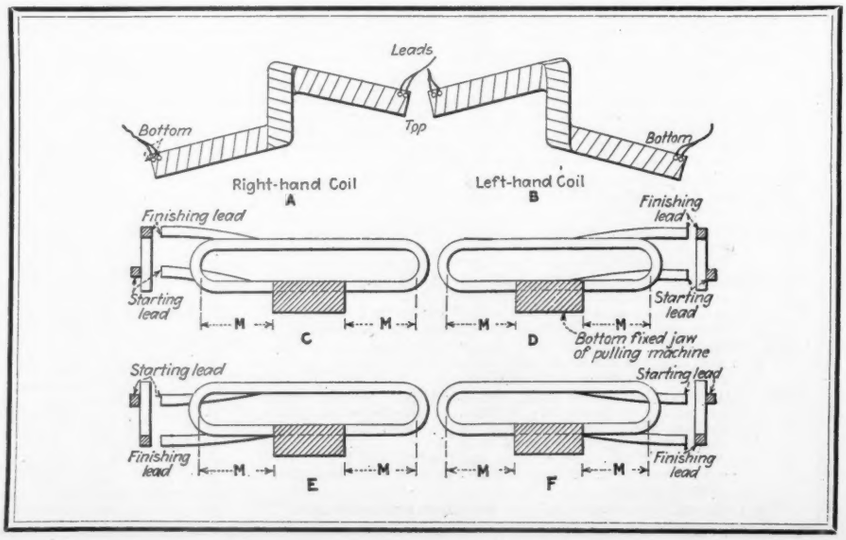


Fig. 4.—These diagrams show the difference between right-hand and left-hand coils. *A* shows a right-hand coil, because when leads are toward the observer right-hand side of coil would be in top of slot of a rotor. *B* is a left-hand coil because the left side of the coil would fall in the top of the slot when leads are toward observer. *C* shows position for pulling right-hand stator coils. *E* shows position for induction-motor, wound-rotor right-hand coils. *F* shows position for induction-motor, wound-rotor left-hand coils.

Table V—Cross-Sectional Area of Bare Copper Straps and Bars*

Size, Inches		Area in	Size, Inches		Area in	Size, Inches		Area in	Size, Inches		Area in	Size, Inches		Area in	Size Inches		Area in
Thickness	Width	Square Inches	Thickness	Width	Square Inches	Thickness	Width	Square Inches	Thickness	Width	Square Inches	Thickness	Width	Square Inches	Thickness	Width	Square Inches
0.0100	¼	0.00747	0.0403	0.400	0.01577	1/16	1⅛	0.10853	1/16	⅜	0.03912	1/16	⅜	0.06842	1/16	⅜	0.15436
0.0126	0.300	0.00374	0.0403	⅜	0.02483	1/16	2	0.12416	1/16	½	0.05212	1/16	½	0.09183	1/16	½	0.19195
0.0126	0.350	0.00437	0.0403	1⅛	0.06010	1/16	2⅛	0.13197	1/16	1/16	0.05895	1/16	1/16	0.10358	1/16	⅝	0.22683
0.0126	⅜	0.00626				1/16	2⅛	0.13978	1/16	⅝	0.06579	1/16	⅝	0.11530	1/16	1	0.30495
0.0126	½	0.00784	0.0415	1⅛	0.04631	1/16	2⅛	0.15541	1/16	¾	0.07946	1/16	¾	0.13727	1/16	1⅛	0.38308
			0.0420	0.300	0.01222	1/16	3	0.18666	1/16	⅞	0.09313	1/16	⅞	0.16070	1/16	1⅛	0.46120
0.0159	0.300	0.00471	0.0420	⅜	0.03112	1/16	1/16	0.01088	1/16	1	0.10680	1/16	1	0.18414	1/16	1⅛	0.53933
0.0159	½	0.00590	0.0430	⅜	0.01572	1/16	⅛	0.01478	1/16	1⅛	0.13415	1/16	1⅛	0.20758	1/16	2	0.61745
0.0190	0.300	0.00569	0.0430	1 1/16	0.05469	0.070	⅛	0.06019	1/16	1⅛	0.16149	1/16	1⅛	0.23102	1/16	2⅛	0.77370
									1/16	1⅛	0.18883	1/16	1⅛	0.25445	1/16	3⅛	1.20339
0.0201	⅛	0.00996	1/16	⅜	0.01710	0.072	0.400	0.02768	1/16	2	0.21618	1/16	1⅛	0.27789			
0.0201	¼	0.01498	1/16	1/16	0.02003	0.072	1	0.07088				1/16	1⅛	0.30133	⅛	⅛	0.13873
0.0201	1	0.02001	1/16	½	0.02296	0.072	1⅛	0.07988	0.118	0.690	0.07843	1/16	1⅛	0.32477	⅛	⅛	0.18414
0.0201	1⅛	0.02503	1/16	1/16	0.02589							1/16	2	0.37164	⅛	⅛	0.23102
			1/16	⅝	0.02882	1/16	¼	0.01822	⅛	¼	0.02936	1/16	2⅛	0.41852	⅛	⅛	0.27370
0.0226	0.300	0.00667	1/16	¾	0.03468	1/16	1/16	0.02310	⅛	⅜	0.04498	1/16	2⅛	0.46539	⅛	⅛	0.32058
0.0226	0.350	0.00780	1/16	⅞	0.04054	1/16	⅛	0.92798	⅛	½	0.04280	1/16	2⅛	0.48883	⅛	1	0.36745
			1/16	1	0.04640	1/16	1/16	0.03286	⅛	⅝	0.05914	1/16	2⅛	0.51227	⅛	1⅛	0.46120
0.0254	¼	0.00621	1/16	1⅛	0.05226	1/16	⅛	0.03775	⅛	⅝	0.06695	1/16	3	0.55914	⅛	1⅛	0.55495
0.0254	0.350	0.00875	1/16	1⅛	0.05812	1/16	⅛	0.04751	⅛	⅞	0.07477	1/16	3⅛	0.65289	⅛	2	0.74245
0.0254	0.400	0.00100	1/16	1⅛	0.06984	1/16	⅛	0.05728	⅛	⅞	0.09039				⅛	2⅛	0.83620
0.0254	⅜	0.01256	1/16	1⅛	0.08155	1/16	⅛	0.06704	⅛	1	0.10602	1/16	⅜	0.08014	⅛	2⅛	0.92995
0.0254	1	0.02526	1/16	2	0.09327	1/16	1	0.07681	⅛	0.900	0.10914	1/16	½	0.10748	⅛	3	1.11745
0.0254	1⅛	0.03796				1/16	1⅛	0.08658	⅛	1	0.12164	1/16	⅝	0.12116	⅛	4	1.49245
0.0285	⅛	0.02120	0.0490	0.181	0.00835	1/16	1⅛	0.09634	⅛	1⅛	0.13727	1/16	¾	0.13336			
						1/16	1⅛	0.11587	⅛	1⅛	0.15289	1/16	⅞	0.16070	⅛	⅛	0.34792
1/16	⅜	0.01150	0.0508	⅛	0.01214	1/16	2	0.15494	⅛	1⅛	0.16852	1/16	1	0.18805			
1/16	½	0.01541	0.0508	¼	0.01849				⅛	1⅛	0.18414	1/16	1	0.21539	1/16	1	0.42995
1/16	1/16	0.01736	0.0508	⅜	0.02484	0.0808	0.150	0.01071	⅛	1⅛	0.19977	1/16	1⅛	0.27008	1/16	1⅛	0.75808
1/16	⅝	0.01932	0.0508	½	0.03754	0.0840	0.300	0.02368	⅛	1⅛	0.21539	1/16	1⅛	0.32477			
1/16	¾	0.02322	0.0508	1	0.05024	0.0860	0.615	0.05130	⅛	2	0.24664				¼	¼	0.29908
1/16	⅞	0.02713	0.0508	1⅛	0.07564				⅛	2⅛	0.27789	⅛	⅜	0.09186	¼	1	0.48658
1/16	1	0.03104	0.0508	1⅛	0.09469	1/16	⅜	0.03327	⅛	2⅛	0.30914	⅛	½	0.12311	¼	1⅛	0.61158
1/16	1⅛	0.03885	0.0508	2⅛	0.12644	1/16	½	0.03912	⅛	3	0.37164	⅛	1/16	0.13873	¼	1⅛	0.73658
1/16	1⅛	0.04666				1/16	⅝	0.04498				⅛	⅝	0.15289	¼	2	0.98658
1/16	2	0.06229	0.0520	0.300	0.01501	1/16	¾	0.05670	1/16	¼	0.06842	⅛	¾	0.18414	¼	3	1.48659
1/16	3⅛	0.09744	0.0550	0.400	0.02135	1/16	⅞	0.06842	1/16	⅜	0.08364	⅛	⅞	0.21539			
			0.0550	⅜	0.04060	1/16	1	0.08014	1/16	½	0.11880	⅛	1	0.24245	1/16	1⅛	0.97096
0.0320	⅛	0.00778	0.0550	1 1/16	0.05778	1/16	1	0.09186	1/16	1⅛	0.15395	⅛	1⅛	0.27370			
0.0320	0.350	0.01098	0.0580	0.400	0.02247	1/16	1⅛	0.10358				⅛	1⅛	0.30495	¼	2	1.23659
0.0330	0.180	0.00570	0.0580	0.860	0.04915	1/16	1⅛	0.11530	1/16	⅜	0.05670	⅛	1 1/16	0.32058			
			0.0587	1	0.05796	1/16	1⅛	0.12702	1/16	½	0.07623	⅛	1⅛	0.36745	¼	1	0.73658
0.0359	⅜	0.01318				1/16	1⅛	0.13873	1/16	⅝	0.09577	⅛	1⅛	0.42995	¼	2⅛	1.65773
0.0159	0.400	0.01408	1/16	⅜	0.02259	1/16	1⅛	0.16217	1/16	¾	0.11383	⅛	1⅛	0.46120			
0.0159	⅜	0.02216	1/16	0.400	0.02416	1/16	2	0.18561	1/16	⅞	0.13336	⅛	2	0.49245	1⅛	2⅛	3.07135
0.0159	1⅛	0.04459	1/16	1/16	0.02650	1/16	2⅛	0.19733	1/16	1	0.15280	⅛	2⅛	0.55495			
0.0159	1⅛	0.05357	1/16	½	0.03041	1/16	2⅛	0.22077	1/16	1⅛	0.19195	⅛	2⅛	0.61745			
			1/16	⅝	0.03822	1/16	2⅛	0.23248	1/16	1⅛	0.21149	⅛	3	0.74245			
0.0365	0.300	0.01066	1/16	¾	0.04603				1/16	1⅛	0.23102	⅛	4	0.99245			
0.0365	0.562	0.02022	1/16	⅞	0.05849	0.100	⅛	0.02285	1/16	1⅛	0.25055	⅛	5	1.22125			
0.0365	1⅛	0.04077	1/16	1⅛	0.05775	0.100	¼	0.03535	1/16	1⅛	0.27008						
0.0365	1⅛	0.04647	1/16	1	0.06166	0.100	1/16	0.04160	1/16	2	0.30914	1/16	½	0.13873			
0.0380	0.350	0.01299	1/16	1⅛	0.06947	0.100	⅜	0.04785	1/16	2⅛	0.34820	1/16	½	0.24273			
			1/16	1⅛	0.07728	0.100	½	0.06035									
0.0403	0.150	0.00569	1/16	1⅛	0.08509	0.100	⅝	0.07285	0.200	0.900	0.17664						
0.0403	¼	0.00972	1/16	1⅛	0.09291	0.100	¾	0.08535	0.229	0.300	0.06591						
						0.100	1⅛	0.18535	0.300	0.400	0.11811						
						0.100	2⅛	0.23535									

* Circ.mils = 0.0000007854 sq.in.

Table VI—Diameter and Area of Round and Square Copper Wire With Various Insulations

*(Blackface type means square wire)

Gage No. B&S	Maximum Diameter				Area of Copper		Gage No. B&S	Maximum Diameter								Area of Copper	
	Bare	S.C.C.	D.C.C.	T.C.C.	Circ.mils	Square Inches		Bare	S.C.C.	D.C.C.	T.C.C.	Enamel	S.C.C. Enamel	D.C.C. Enamel	S.SilkC. Enamel	Circ.mils	Square Inches
*4/0	0.460	.....	0.483	0.492	265,152	0.20825	*12	0.0808	0.093	0.093	0.098	.....	.....	.....	.....	7,868	0.00618
4/0	0.460	.....	0.478	0.487	211,600	0.16619	12	0.0808	0.086	0.091	0.096	0.0832	0.08825	.....	.....	6,530	0.00513
*3/0	0.410	.....	0.433	0.442	209,345	0.16442	*13	0.0720	.....	0.083	0.088	.....	.....	.....	.....	6.162	0.00484
3/0	0.410	.....	0.428	0.437	167,800	0.13179	13	0.0720	0.077	0.081	0.086	0.0743	0.07925	.....	.....	5,178	0.00407
*2/0	0.365	.....	0.388	0.397	165,037	0.12972	14	0.0641	0.069	0.073	0.078	0.0663	0.07125	.....	.....	4,107	0.00323
2/0	0.365	.....	0.383	0.392	133,100	0.10454	15	0.0571	0.062	0.066	0.071	0.0593	0.06425	0.0683	.....	3,257	0.00256
* 0	0.325	.....	0.348	0.357	130,124	0.10220	16	0.0508	0.056	0.060	0.065	0.0529	0.05775	0.0620	.....	2,583	0.00203
0	0.325	.....	0.343	0.352	105,500	0.08286	17	0.0453	0.050	0.054	0.059	0.0472	0.05225	0.0563	.....	2,048	0.00161
* 1	0.289	.....	0.312	0.321	102,292	0.08034	18	0.0403	0.045	0.049	0.054	0.0422	0.04725	0.0513	.....	1,624	0.00128
1	0.289	.....	0.307	0.316	83,690	0.06573	19	0.0359	0.041	0.045	0.050	0.0377	0.04275	0.0468	.....	1,288	0.00101
* 2	0.258	.....	0.281	0.290	80,203	0.06300	20	0.0320	0.037	0.041	0.046	0.0338	0.03875	0.0428	.....	1,022	0.00080
2	0.258	.....	0.276	0.285	66,370	0.05213	21	0.0285	0.033	0.038	0.043	0.0302	0.03525	0.0393	.....	810.1	0.00064
* 3	0.229	.....	0.252	0.261	62,732	0.04927	22	0.0254	0.0305	0.035	0.039	0.0271	0.03225	0.0360	.....	642.4	0.00050
3	0.229	.....	0.247	0.256	52,630	0.04134	23	0.02260	0.029	0.032	0.037	0.0242	0.02900	0.0333	.....	509.5	0.00040
* 4	0.204	.....	0.227	0.236	50,737	0.03985	24	0.0201	0.025	0.029	0.034	0.0216	0.02650	0.0305	.....	404.0	0.00032
4	0.204	.....	0.222	0.231	41,740	0.03278	25	0.0179	0.023	0.027	0.032	0.0193	0.02450	0.0283	.....	320.4	0.00025
* 5	0.182	.....	0.205	0.214	39,725	0.03120	26	0.0159	0.020	0.025	0.030	0.0172	0.02225	0.0263	.....	254.1	0.00020
5	0.182	.....	0.200	0.209	33,100	0.02600	27	0.0142	0.018	0.023	0.028	0.0155	0.02025	0.0245	0.0173	201.5	0.00016
* 6	0.162	.....	0.183	0.191	32,340	0.02540	28	0.0126	0.016	0.022	0.027	0.0139	0.01875	.....	0.0155	159.8	0.00013
6	0.162	.....	0.178	0.186	26,250	0.02062	29	0.0113	0.014	0.020	0.025	0.0125	0.01750	.....	0.0143	126.7	0.00010
* 7	0.144	.....	0.163	0.171	25,439	0.01998	30	0.0100	0.013	0.019	0.024	0.0111	0.01600	.....	0.0130	100.5	0.000079
7	0.144	.....	0.160	0.168	20,820	0.01635	31	0.0089	0.011	0.018	0.023	0.0100	0.91500	.....	0.0120	79.70	0.000063
* 8	0.129	.....	0.146	0.153	19,951	0.01567	32	0.0080	0.010	0.017	0.022	0.0090	0.01400	.....	0.0110	63.21	0.000050
8	0.129	.....	0.143	0.150	16,510	0.01297	33	0.0071	0.009	0.016	.....	0.0080	0.01325	.....	0.0098	50.13	0.000039
* 9	0.114	.....	0.129	0.135	16,221	0.01028	34	0.0063	0.008	.....	.....	0.0072	0.01225	.....	0.0090	39.75	0.000031
9	0.114	.....	0.126	0.132	13,090	0.01274	35	0.0056	0.007	.....	.....	0.0064	0.01150	.....	0.0083	31.52	0.000025
* 10	0.102	.....	0.115	0.120	12,783	0.01004	36	0.0050	0.006	.....	.....	0.0058	0.01100	.....	.....	25.00	.000020
10	0.102	0.107	0.112	0.117	10,380	0.00815	37	0.0045	0.006	.....	.....	0.0052	.....	.....	.....	19.83	0.000016
* 11	0.0907	.....	0.103	0.108	10,033	0.00788	38	0.0040	0.005	.....	.....	0.0046	.....	.....	.....	15.72	0.000012
11	0.0907	0.096	0.101	0.106	8,234	0.00647											

S.C.C. = single-cotton-covered; D.C.C. = double-cotton-covered; T.C.C. = triple-cotton-covered; S.SilkC. = single-silk-covered.

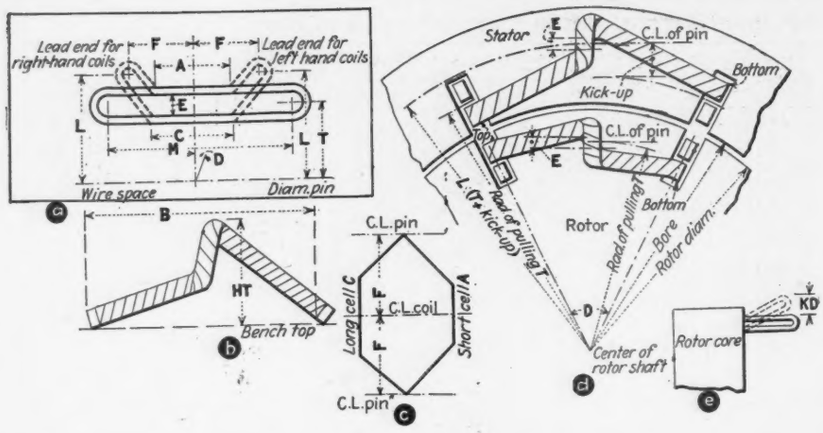


Fig. 3.—How dimensions of motor coils are entered on card diagram. (*a*) Shows the card diagram filled in. (*d*) Dimension letters correspond to card at (*a*). (*b*) Shows how height of coil (*HT*) is measured. (*c*) Shows how length of coil is figured. (*e*) "Kickdown" of rotor coil is shown at *KD*. The dotted lines in (*e*) show the coil as pulled and the full lines show the coil with a correct "kick-down" so that the coil ends are below the level of the rotor iron. This is the diagram in *D* of Fig. 1.

Table IV—Dimensions and Cross-Sectional Area of Bare and Double-Cotton-Covered Ribbon Wire

Size, Inches				Area of Copper		Size, Inches				Area of Copper	
Bare		Insulated				Bare		Insulated			
Thick-ness	Width	Thick-ness	Width	Circ. Mils	Square Inches	Thick-ness	Width	Thick-ness	Width	Circ. Mils	Square Inches
0.0126	0.187	0.0295	0.2015	2,964	0.00232	0.0720	0.210	0.0890	0.2240	18,184	0.01428
0.0126	0.250	0.0295	0.2645	3,967	0.00311	0.0720	0.315	0.0890	0.3300	27,810	0.02184
						0.0740	0.205	0.0910	0.2190	18,248	0.01433
0.0159	0.187	0.0330	0.2015	3,727	0.00292	0.0760	0.134	0.0930	0.1473	11,900	0.00934
0.0159	0.250	0.0330	0.2645	4,992	0.00392	0.0780	0.155	0.0950	0.1685	14,326	0.01125
						0.0790	0.125	0.0960	0.1383	11,506	0.00903
0.0201	0.250	0.0370	0.2645	6,288	0.00493						
0.0254	0.250	0.0425	0.2645	7,909	0.00621	0.0808	0.108	0.0978	0.1250	10,043	0.00788
0.0285	0.120	0.0455	0.1332	4,133	0.00324	0.0808	0.115	0.0978	0.1323	10,764	0.00845
0.0285	0.150	0.0455	0.1635	5,222	0.00410	0.0808	0.150	0.0978	0.1635	14,365	0.01128
0.0285	0.207	0.0455	0.2210	7,291	0.00572	0.0808	0.175	0.0978	0.1888	16,937	0.01330
						0.0808	0.200	0.0978	0.2140	19,509	0.01532
0.0320	0.100	0.0490	0.1130	3,794	0.00298	0.0808	0.250	0.0978	0.2645	24,653	0.01936
0.0320	0.132	0.0490	0.1453	5,098	0.00400	0.0808	0.500	0.0978	0.5150	50,372	0.03956
0.0320	0.180	0.0490	0.1938	7,084	0.00554						
0.0320	0.250	0.0490	0.2645	9,906	0.00778	0.0830	0.145	0.1000	0.1585	14,256	0.01119
0.0320	0.375	0.0490	0.3900	14,999	0.01178	0.0830	0.181	0.1000	0.1948	18,061	0.01418
0.0370	0.092	0.0540	0.1050	3,960	0.00311	0.0840	0.118	0.1010	0.1353	11,553	0.00907
0.0390	0.123	0.0560	0.1363	5,693	0.00447	0.0840	0.300	0.1010	0.3150	31,019	0.02436
0.0390	0.170	0.0560	0.1838	8,027	0.00630	0.0840	0.360	0.1010	0.3750	37,436	0.02940
0.0390	0.263	0.0560	0.2778	12,645	0.00993						
						0.0850	0.152	0.1020	0.1655	15,383	0.01208
0.0403	0.160	0.0573	0.1735	7,765	0.00609	0.0850	0.195	0.1020	0.2090	20,037	0.01573
0.0403	0.205	0.0573	0.2190	10,075	0.00791						
0.0403	0.250	0.0573	0.2645	12,383	0.00972	0.0880	0.437	0.1050	0.4533	47,897	0.03761
0.0403	0.315	0.0573	0.3300	15,719	0.01234	0.0920	0.154	0.1090	0.1675	16,972	0.01333
0.0403	0.375	0.0573	0.3900	18,798	0.01476	0.0940	0.315	0.1110	0.3300	36,634	0.02877
0.0420	0.135	0.0590	0.1473	6,683	0.00524	0.0960	0.205	0.1130	0.2190	23,990	0.01884
0.0430	0.110	0.0600	0.1230	5,517	0.00433	0.0960	0.450	0.1130	0.4650	53,937	0.04236
0.0453	0.088	0.0623	0.1010	4,515	0.00354						
0.0453	0.145	0.0623	0.1585	7,804	0.00612	0.0980	0.130	0.1150	0.1473	15,154	0.01190
						0.1000	0.315	0.1170	0.3300	39,040	0.03066
0.0470	0.170	0.0640	0.1838	9,570	0.00751						
0.0474	0.150	0.0645	0.1635	8,439	0.00662	0.1020	0.132	0.1190	0.1493	16,076	0.01262
0.0474	0.270	0.0645	0.2848	15,682	0.01231	0.1020	0.175	0.1190	0.1888	21,660	0.01701
0.0474	0.315	0.0645	0.3300	18,397	0.01444	0.1020	0.205	0.1190	0.2190	25,556	0.02007
						0.1020	0.270	0.1190	0.2840	33,998	0.02670
0.0490	0.095	0.0660	0.1080	5,271	0.00414						
0.0490	0.134	0.0660	0.1473	7,704	0.00605	0.1060	0.242	0.1230	0.2560	31,594	0.02481
0.0490	0.181	0.0660	0.1948	10,637	0.00835	0.1060	0.286	0.1230	0.3000	37,533	0.02947
0.0490	0.374	0.0660	0.3890	22,678	0.01781						
0.0490	0.437	0.0660	0.4520	26,608	0.02089	0.1080	0.115	0.1250	0.1320	14,747	0.01158
						0.1100	0.188	0.1270	0.2020	25,264	0.01984
0.0508	0.070	0.0678	0.0868	3,822	0.00300						
0.0508	0.117	0.0678	0.1303	6,863	0.00539	0.1140	0.144	0.1313	0.1610	19,835	0.01557
0.0508	0.161	0.0678	0.1745	9,708	0.00762	0.1140	0.412	0.1313	0.4270	58,735	0.04613
0.0508	0.250	0.0678	0.2645	15,464	0.01214						
						0.1160	0.335	0.1333	0.3500	48,411	0.03802
0.0520	0.205	0.0690	0.2190	12,834	0.01008	0.1160	0.350	0.1333	0.3650	50,627	0.03976
0.0540	0.078	0.0710	0.0950	4,566	0.00358						
0.0550	0.095	0.0720	0.1080	5,826	0.00457	0.1200	0.220	0.1334	0.2340	32,546	0.02556
0.0570	0.134	0.0740	0.1473	8,836	0.00694	0.1230	0.465	0.1403	0.4800	71,756	0.05635
0.0590	0.150	0.0760	0.1635	10,317	0.00810	0.1290	0.175	0.1493	0.1950	27,676	0.02173
0.0590	0.205	0.0760	0.2190	14,449	0.01134	0.1290	0.210	0.1493	0.2270	33,425	0.02625
0.0590	0.315	0.0760	0.3300	22,712	0.01783	0.1290	0.250	0.1493	0.2570	39,995	0.03141
						0.1290	0.320	0.1493	0.3380	51,492	0.04044
0.0600	0.117	0.0770	0.1303	7,954	0.00624	0.1290	0.412	0.1493	0.4300	66,603	0.05231
0.0600	0.130	0.0770	0.1433	8,948	0.00702						
0.0620	0.088	0.0790	0.1050	5,896	0.00463	0.1440	0.300	0.1645	0.3180	53,937	0.04236
						0.1460	0.185	0.1665	0.2060	33,509	0.02631
0.0641	0.095	0.0810	0.1120	6,686	0.00525	0.1560	0.312	0.1768	0.3300	61,103	0.04799
0.0641	0.250	0.0810	0.2645	19,337	0.01518	0.1620	0.250	0.1845	0.2690	50,499	0.03966
0.0641	0.312	0.0810	0.3270	24,397	0.01916	0.1820	0.290	0.2068	0.3120	64,800	0.05089
0.0660	0.154	0.0830	0.1675	11,874	0.00932	0.2040	0.270	0.2290	0.2950	67,728	0.05319
0.0670	0.112	0.0840	0.1250	8,487	0.00666	0.2040	0.320	0.2290	0.3420	80,715	0.06339
0.0670	0.125	0.0840	0.1383	9,596	0.00753						
						0.2150	0.235	0.2403	0.2600	61,929	0.04863
0.0680	0.091	0.0850	0.1080	6,812	0.00535	0.2290	0.300	0.2543	0.3260	85,070	0.06681
0.0680	0.180	0.0850	0.1938	14,518	0.01140	0.2580	0.365	0.2835	0.3910	115,631	0.09081
0.0680	0.400	0.0850	0.4150	33,565	0.02636	0.2700	0.283	0.2958	0.3080	93,018	0.07305
						0.2890	0.310	0.3150	0.3360	109,800	0.08623
0.0700	0.250	0.0870	0.2645	21,215	0.01666						
0.0700	0.265	0.0870	0.2798	22,552	0.01771	0.3000	0.400	0.3260	0.4260	148,519	0.11664
0.0720	0.130	0.0890	0.1433	10,851	0.00852	0.3000	0.500	0.3260	0.5220	186,716	0.14664
0.0720	0.150	0.0890	0.1635	12,684	0.00996	0.3250	0.350	0.3513	0.3760	140,561	0.11039

length *A* is the length of the slot section of the coil. *B* is the distance from the center line of the bottom of the top half of the coil to the center line of the upper part of the bottom half of the coil. It is more easily measured as at (*b*) in Fig. 3. *D* is the angle to which the coil is pulled and is equal to (360 deg./*N*) ×coil pitch, where *N* is the total number of slots in the machine. The total inside length of the shuttle is *M*+*E*, where *E* is the diameter of pins used on the shuttle. *T* is the distance from the rotor-shaft center to the center of the slot. To get *T* for a rotor, subtract one-half the depth of the slot from the radius of the rotor. For a stator, add one-half the slot length to the radius of the stator. The dotted line in the card diagram represents the coil pulled to its final shape with the "kick-up" put in the coil. The "kick-up" is put in a stator coil so that the ends of the coil will not project above the level of the stator iron and rub on the rotor. The dimension *L* is best determined by winding a trial coil, placing it in the stator and noting the amount of "kick-up" necessary to make the coil ends come below the iron. This amount of "kick-up" is given to the coil, and it is tried again. For rotor coils a "kick-down" is often required; i. e., when the distance between the rotor iron and the top of the coil is less than ⅛ in. The lettering on either side of diagram (*a*) in Fig. 3 and the sketches *C*, *D*, *E* and *F*, Fig. 4, explain the way the loops should be put in the pulling machine for right-hand or left-hand coils. Dimensions *A* and *C* in Fig. 3 (*a*) are the slot section (cells) of the coil which fit in the blocks on the pulling machine. As these blocks have ends rounded with ¼-in. radius, they are ½-in. longer than the lengths *A* and *C* in (*a*), Fig. 3. In this diagram *C* is shown longer than *A*, which holds for all stator coils, as *C* will be the top half of the coil. A stator coil si pulled inverted. For a rotor the side *A* will be the top of the coil and should be the longer. (*Continued on page* 310.)

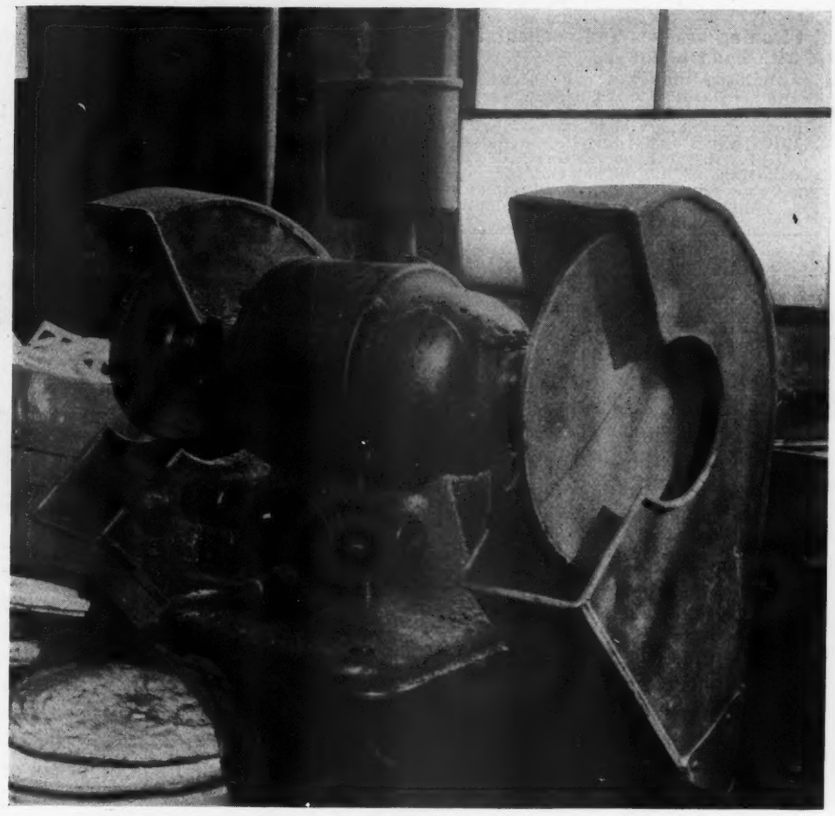
Some of the Points That Need Watching on

Small Motors That Drive Machines

in Factories Where Dust and Dirt Accumulates

By H. E. EWALT

Formerly Maintenance Engineer, Benjamin Electric Manufacturing Company. Chicago, Ill.



Accumulations of fuzz and dirt of this kind, if allowed to remain, will draw the oil out of the bearings and may cause fires when motors are not enclosed.

CLEANING is an important part of the inspection routine for fractional horse-power motors used in ordinary factory work. When a motor becomes dirty and is allowed to run in this condition, the dirt or dust tends to form an inflammable fuzz like a collection of loose cotton. Sparks from the brushes, from open circuits in the armature, or from starting the motor too rapidly may set fire to this fuzz and with the high velocity of the air around the armature, a small spark will often be fanned into a flame. Even when this fuzz does not burn with a flame, it will smolder and produce such a heavy smoke that motors in this condition appear as though they were burning out completely. This smoke often frightens machine operators, and they will use a fire extinguisher before the real conditions are understood. Then the winding is either so damaged that repairs are needed or there is a delay until it is dried out. When a motor is in this condition it is best to allow it to smoke, but turn off the current. The motor end plate should then be pulled off and the burning fuzz taken out as quickly as possible. This can be done with a rag or stick or with the bare hands. It is necessary to remove every particle of burning material. Otherwise, the motor will smoke again when it is started. This fuzz also has a tendency to absorb oil and if allowed to accumulate, it will empty the bearing reservoirs. In addition, bearings are affected by dirt collecting in them as it contains gritty substances and may produce excessive wear. In oil-ring bearings, dirt in the housing has a tendency to retard the proper working of the oil rings.

When dirt and oil unite on a commutator they either cause poor brush contact or the gumming up of the brushes so that they cannot move properly in the brush holder. When kept from working freely brushes soon wear until contact ceases, but before the armature stops there are times when the brush makes and breaks contact, drawing a flash or heavy arc on the commutator and either burning it badly or heating it so that the armature leads become unsoldered, thus causing open circuits. When armature leads become unsoldered from the commutator, it may be burned at the bars where the open circuits exist, producing flat spots and poor commutation.

REPAIR WORK on small motors used in ordinary service in a factory can be held to a minimum by keeping them clean. Moreover, this is insurance against fires around inflammable materials. In this article practical suggestions are given for inspecting small motors and making the electrical and mechanical repairs that are needed from time to time.

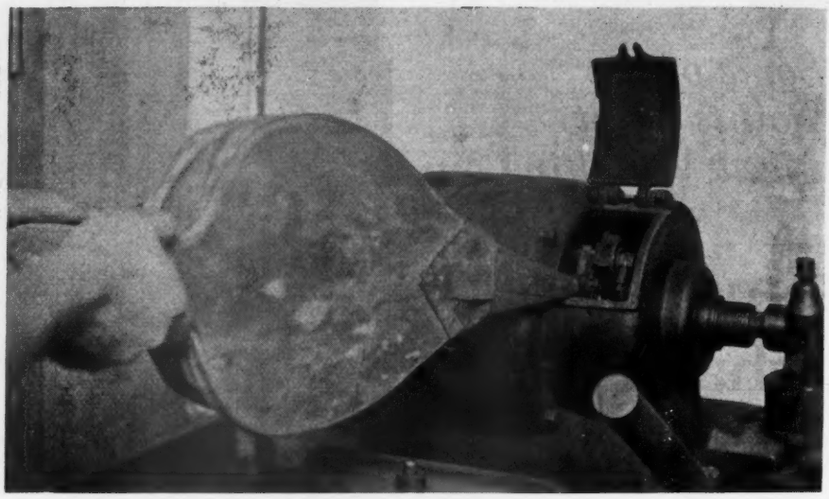
The ventilation of a motor is also affected by accumulations of dirt, since these accumulations choke the air entrance. Ventilation is important when a motor is in operation for several hours. If the circulation of air is retarded the motor heats up, overbaking the insulating varnish on the windings and evaporating the lubricating oil.

The inspection and maintenance routine which the writer has found satisfactory to insure the proper operation of a large number of motors, many of which are of fractional horse-power rating, involves the use of blue print plans showing the location of the various motors and a report sheet which is filled out by the inspector.

In preparing the blue prints a separate print is made for each floor of

Cleaning brushes and commutators with hand bellows.

A bellows makes a convenient and quick cleaning tool for the removal of dirt lodged in pockets difficult or slow to reach with a rag or brush. With a bellows there is no danger of blowing oil or water into the winding or of doing the damage which sometimes results from the use of compressed air at high velocity.



the factory. The location of each motor is indicated by a small circle and a number. A legend at the bottom of the print shows the horsepower of the motor and the machine driven by it. All motors are inspected and cleaned once a week. A separate report sheet, such as shown below is also made out for each floor. This sheet carries the number and size of the motor and the machine driven with four columns each headed by the day of the month on which the inspection is made. In these columns the findings of the inspector can be entered for each motor as shown on the form below. Each report sheet thus covers one month, or four inspections.

A painter's duster is a handy device for cleaning small motors for inspection. For interior cleaning hand bellows or compressed air at a pressure of not more than 30 lbs. per sq. in. are effective. In using compressed air for this purpose care must be taken not to damage the insulation on the windings or break or disconnect the wires by too high pressure. Water often collects in compressed air reservoirs, together with some oil that leaks through the compressor cylinder, and unless these are drained from the tank or a water separator is used they will be blown into the motor. A small-size rubber hose is safer than a metal nozzle as an air outlet. With metal nozzles there is a chance of short circuiting, grounding or causing mechanical damage when cleaning motors in operation. A fractional horse-power motor in ordinary service, if cleaned once a month with compressed air, should remain in satisfactory condition. Compressed air has a tendency to remove the oil from oil ring bearings, so it is necessary to refill the bearings after each cleaning.

The armature and field coils should be varnished or painted with an insulating paint at least once a year. This will help to keep the motors clean and when a shorted coil or heavy overload causes heating, the smell of burning varnish gives a good indication of trouble. Dolph's "Electric Lacquer" meets the needs of this kind of work as it air-dries with a smooth finish and is a good insulator. Motors painted with this lacquer have the appearance of being cared for. While motor troubles cannot all be laid to dirt, in many cases the starting point can be traced to that source.

Overloaded motors are easily de-

BENJAMIN ELECTRIC MANUFACTURING COMPANY

120 South Sangamon Street, Chicago.

MAINTENANCE OF MOTORS ON FOURTH FLOOR. MONTH OF FEBRUARY, INSPECTION EVERY WEDNESDAY.

		1st	8th	15th	22nd
NO. 401	DYNAMO H.V.W.	✓	✓	✓	✓
402	LINE SHAFT 5 H.P.	Loose pulley set up set screw	Brush shaft on pulley	✓	Loose pulley ✓
403	RIVETER 1/3 H.P.	✓	Turned Commutator	✓	✓
404	VENT. FAN 1 H.P.	✓	✓	✓	✓
405	" " "	✓	✓	✓	✓
406	SHELL MACH. 1/12 H.P.	✓	✓	✓	✓
407	RIVETER 1/3 H.P.	take apart and clean	Cleaned	✓	✓
408	" "	take down for repair	Repaired	✓	✓
409	" "	✓	✓	✓	✓
410	GRINDER 1/6 H.P.	Bearing Worn	Bearing worn	Bearing Worn	✓
411	SCREW DRIVER 1/12 H.P.	✓	✓	✓	✓
412	" " "	✓	✓	✓	✓
413	" " "	✓	✓	✓	✓
414	GRINDER 1/6 H.P.	✓	✓	✓	✓
415	A. C. GENERATOR	✓	✓	✓	✓
416	STORAGE BATTERIES	✓	✓	✓	✓
417	GENERATOR	✓	✓	✓	✓
418	GRINDER 1/2 H.P.	Air duct Loose	Fastened air duct	✓	✓
419	BUFFER 5 H.P.	Fiber Washer	Fiber washer	✓	✓
420	" 3 H.P.	Watch back bearing	→	→	→
421	" 8 H.P.	✓	✓	✓	✓
422	" 5 H.P.	✓	✓	✓	✓
423	BLOWER 10 H.P.	Tighten Set Screw	Repaired	✓	✓
424	AUTOMATIC 1/2 H.P.	Starter for trouble	✓	✓	✓

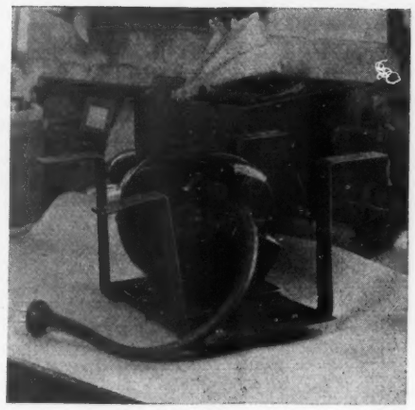
The motor inspector makes his report on this sheet.

The inspector carries this report form with him on his rounds and notes the repairs needed by each motor. A check mark indicates satisfactory condition. Inasmuch as each sheet covers four inspections, it is easy to determine the promptness with which needed repairs have been made.

tected when they heat to such an extent that the insulating varnish begins to give off a burnt smell, or the brushes spark considerably, or the speed of the motor is greatly reduced. An overloaded motor should be detected when first installed by the use of an ammeter and voltmeter. The latter is not required if the voltage is definitely known. The ammeter is connected in series with the motor and when it is running with full load the amount of current shown by the ammeter compared with the nameplate rating of the motor gives an indication of the extent to which the motor is loaded. Motors are usually capable of standing 25 per cent overload, but where a constant overload is applied it is advisable to install a motor of the proper rating. Continuous overload causes heating of the commutator, which, in turn, heats the soldered connections until the armature leads are loosened, causing open circuits.

Spare motor ready for replacement service under work tables.

Motors like this one are kept ready for use in emergency when it is necessary to remove a motor supported on a bracket under a work table. If the motor to be replaced is mounted on top of the table the bracket can be removed from the spare by loosening the two bolts holding the motor and bracket together.



The Commutator Is Usually the Weak Spot in an Armature

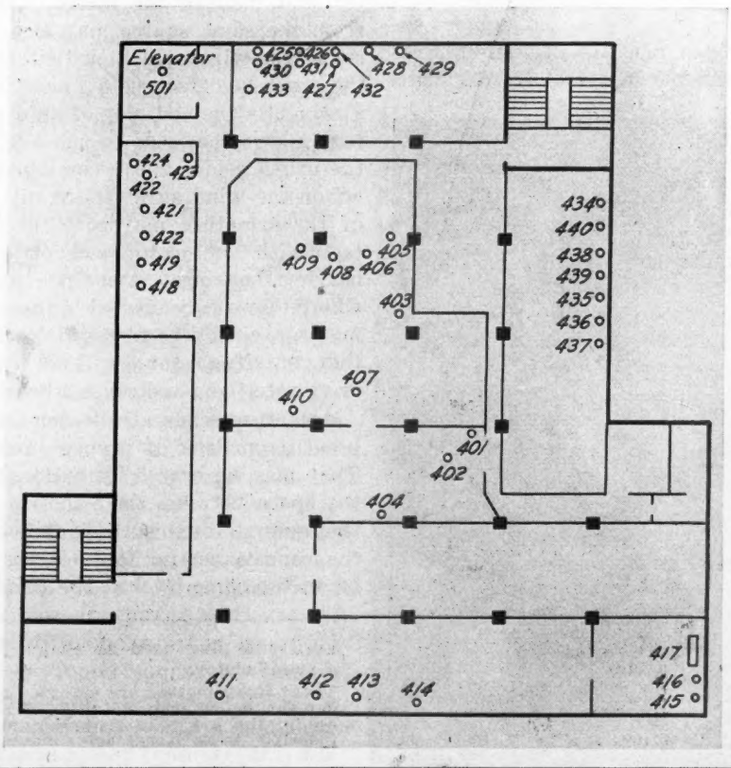
The commutator is the place to look for short or open circuits or grounds in the armature. The armature winding, if properly applied, is the last place to look for these unless the machine has been subjected to abuse of some kind. If it has not been properly wound and shorts or open circuits occur, it is advisable to rewind it properly. Short circuits in the commutator may be traced to the following causes: (1) Oil and carbon dust; (2) oil, dust and fine copper from sandpapering the commutator; (3) improper turning of the commutator, leaving threads of copper which work over the mica insulation; (4) poor soldering of leads allowing the solder to extend over the mica insulation. If a short-circuited commutator is allowed to run, the bars at the location of the trouble will turn a pinkish color and the short circuit will be found between the two colored bars. Also the shorted coil will heat up and may burn the insulation. By feeling a heated coil it can be traced to its commutator bar and the short found and removed.

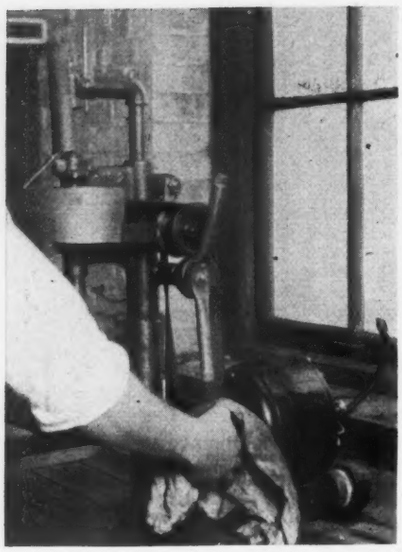
If there is a short circuit between commutator bars, it can best be cleared by the aid of commutator crowbars. These can be made of hacksaw blades by removing all the teeth and grinding to various points, edges or hooks convenient for digging out the short circuit. Where there is a short circuit between bars the mica often burns to black dust. In making repairs it is necessary to remove every particle of this black dust, since it forms a part of the short circuit. After the short has been cleaned away until the mica segment is white, the hole can be filled with an insulating compound used for repairing commutators or with a mixture of shellac and plaster of Paris and mica dust or with a mixture of silicate of soda (which is known as water glass), plaster of Paris and mica dust. The propor-

Motor-location sheets like these facilitate inspection and maintenance work.

A separate blue print is made for each floor. The location of each motor is indicated by a small circle which is distinguished by a number. At the bottom of the blue print the size and duty of each motor is given opposite the motor number. With this sheet as a guide a new inspector would have no difficulty in locating any desired motor.

401 Dynamo H.V.W.
402 Line shaft 5 hp.
403 Riveter 1/3 hp.
404 Vent. fan 1 hp.
405 Vent. fan 1 hp.
406 Shell mach. 1/12 hp.
407 Riveter 1/12 hp.
408 Riveter 1/12 hp.
409 Riveter 1/12 hp.
410 Grinder 1/6 hp.
411 Screwdriver 1/12 hp.
412 Screwdriver 1/12 hp.
413 Screwdriver 1/12 hp.
414 Grinder 1/6 hp.
415 A. C. generator
416 Generator
417 Storage batteries
418 Grinder 1/2 hp.
419 Buffer 5 hp.
421 Buffer 8 hp.
422 Buffer 5 hp.
423 Blower 10 hp.
424 Automatic 1/2 hp.
425 Vent. fan 1/6 hp.
426 Vent. fan 1/6 hp.
427 Vent. fan 1/6 hp.
428 Vent. fan 1/6 hp.
429 Vent. fan 1/6 hp.
430 Revolving disc 1/12 hp.
431 Revolving disc 1/12 hp.
432 Revolving disc 1/12 hp.
433 Chain conveyor
434 Vent. fan
435 Vent. fan
436 Vent. fan
437 Vent. fan
438 Buffer 1 hp.
439 Buffer 1 hp.
440 Buffer 1 hp.
501 Elevator 10 hp.



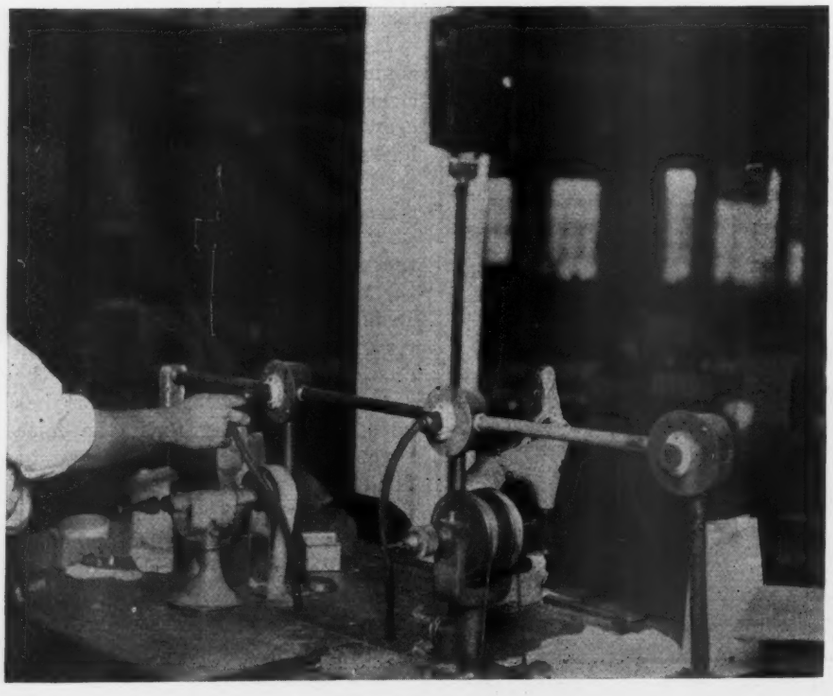


Excess oil should not be allowed to remain on small motors.
Oil from the bearings, if allowed to seep out onto the frame or armature, will collect and hold dust and lint. If allowed to accumulate, the dirt will draw all the oil out of the bearings.

tions should be about two parts plaster of Paris, one part powdered mica and enough shellac or water glass to make a thick paste. These two compounds will wear much the same as mica, but must be dried before applying current to the motor. It is necessary to check up on such repairs, since filling a commutator does not make as good a job as when a new mica segment has been put in, altho the filling may last for years.

To prevent short circuits in the commutator or armature leads, the space between the leads on the commutator segments should be cleaned and varnished, except over the brush contact surface. One of the most common causes of short circuits is incorrect turning of the commutator. When a commutator is turned in a lathe and the end and shoulder where armature leads are soldered are left square, trouble may be expected. When the corners are left square the mica cannot support itself up to the corner and so is soon broken out, making pockets where short circuits may form. All sharp edges of commutators should be rounded enough so that the mica is able to hold up. In soldering leads it is best to elevate the armature so that the heated solder will run towards the commutator rather than under the winding, where it may short circuit the commutator or winding leads.

Open circuits in the armature are recognized at the commutator. An open circuit causes a flash every time the segment to which the open coil is connected leaves the brush. This flash, resulting from the breaking of the armature circuit every time this segment passes the brush, burns the segment and mica insulation, since it travels over the open bar to the next one and sometimes goes the full distance around the commutator. The burning of a segment lowers its height, making it necessary to turn the commutator in a lathe to bring all bars even. When a segment becomes too hot the insulation gives way and the segment becomes loose.



Cord and plug used as switch for a small motor.
These small motors are mounted under the bench and switched off and on by the aid of a separable plug inserted in a receptacle mounted above the bench. This scheme is found to be both practical and cheap to maintain.

Replacing a damaged small motor on a bench machine.
To replace a motor when this type of mounting is used, all that is required is to pull out the attachment plug, remove the belt, take out four screws, lift out the damaged motor and put in the spare one and reverse the operations mentioned. The entire change can be made in about the time required to describe it. It will be noted that the spare motor is provided with a double pulley to make it fit into a number of different services.

A motor having an open circuit area gradually begins to arc and continues to arc more and more. This is undesirable, as it is liable to start a fire or ruin the motor. Open circuits are often caused by a poor brush contact heating the commutator and melting the solder. Heat from the same source may also unsolder the wires which lead either to the brush holders or field connections. Frequently the end play of an armature allows the leads to rub against the brush holder and become broken off or the winding at the front end of the armature may come in contact with the motor end plate or bearing housing. Armature leads, where they are connected to the commutator, should be fastened down so that centrifugal force will not loosen or vibrate them and cause a break.

Armature leads also loosen up or break from lack of proper support. They may be braced by building up the space between the winding and the commutator to such a height that the leads connecting to the latter will be on the same level at the point of

connection. After soldering, wind strings around them. The varnish, string and bracing will make the leads tight and solid. By bracing armature leads, setting end play of the armature to 1/16 in., and placing other motor wires in such a position that they cannot rub against winding and brushes, open circuits will be eliminated except as a result of short circuited commutator segments.

To repair an open circuit where the lead is loose from the commutator, lift up the lead and clean it and the commutator slot, so that a perfect soldered joint can be made. When the armature lead is broken or a broken coil turn is to be connected, a wire the same size as used for the winding can be wound around the broken wire several times, after the insulation has been removed and the surface cleaned, then pressed together with a pair of smooth pliers and soldered. If a very short end is to be picked up it may be necessary to form the connecting coil around another piece of wire of the same size used in the armature coil, and then slip it over the broken lead of the latter. In this way it is often possible to save a coil winding that would otherwise be beyond repair. Winding connections on a motor should not be soldered with acids as a flux, since the corrosion which these cause will make trouble later. Allen's soldering paste is safe to use if after soldering the connections are washed with gasoline. Rosin or non-conducting soldering flux does not insure perfect soldered connections in all cases, as the solder does not flow as freely as when a stronger flux is used.

A Rubber Band Will Keep Segments Together When Repairing Commutator

Repairing of commutators requires some skill in holding the segments straight after they have been loosened to replace mica segments. On fractional horse-power motors some commutators are riveted together and some are screwed together with a nut and angle washer. When they are riveted together the only way of repairing is to fill with a commutator compound or force mica with shellac into the pitted sections. If a riveted commutator is grounded and the ground cannot be located, the best thing to do is to put on a new commutator. With a commutator of the screw type the nut and

A paint brush is convenient for dusting off the commutator brushes and connections.

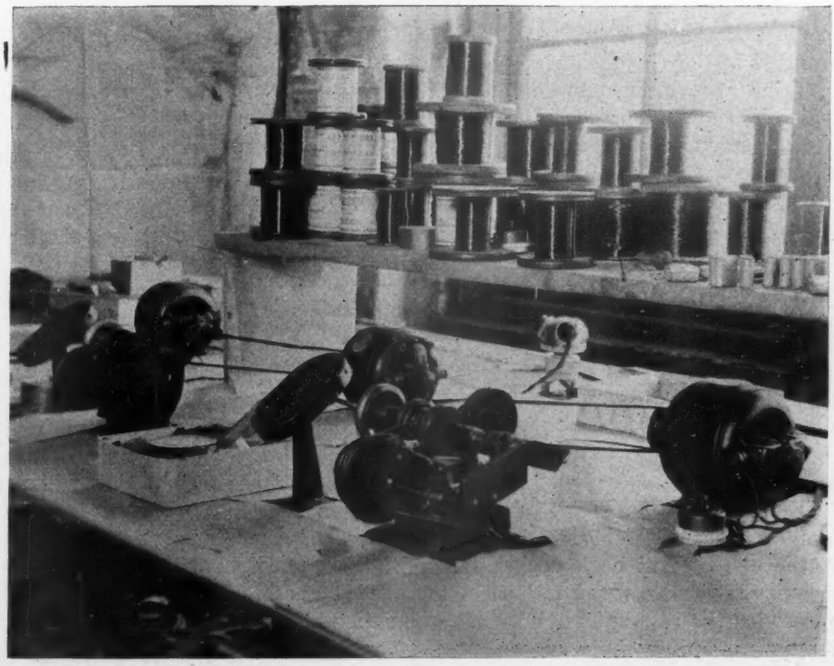
washer holding the segments together can be removed, after winding a rubber band tightly over the segments. The defective mica segment may then be removed and another cut to the same size and put in place. The elasticity of the rubber band allows this to be done, while keeping the segments together. If the segments fall apart it is almost impossible to get them together again in proper shape.

In replacing a mica segment it is necessary to put in a piece of the same size as the one removed. Otherwise the segments will twist out of shape when tightened and leave the commutator with a dirt pocket for future trouble. Micanite insulation comes in various sizes and kinds, but for commutator segments, thicknesses of 0.025 in. or 0.030 in. are mostly used. Molding micanite is used for making collars or washers for commutators. When this is heated it can be pressed into various shapes or forms, becoming hard again when cooled.

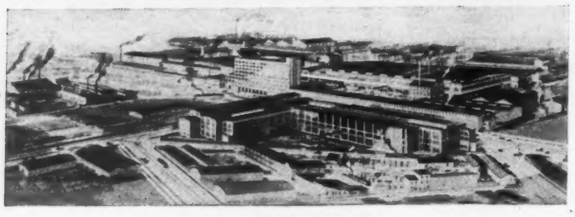
Care of Brushes and Brushholders

Brush holders should be maintained so that the brushes can move freely up and down in them. Spring tension should be sufficient to hold the brush on the commutator surface and make good contact. To test the brush contact of a fractional horsepower motor, place a strip of No. 00 sandpaper under the brush and move the sandpaper up and down to grind off some of the brush. The amount of carbon removed in this way gives an idea as to the pressure applied on the commutator and a little practice in this test will enable the workman to judge the proper brush pressure in each case. (*Continued on page* 312)

Motors mounted on top of a table are easy to inspect and clean. The shelf above the motors provides a stockkeeping space and also serves as a guard for the motor. The motor end plates are open so that it is easy to detect sparking or other signs of trouble as soon as they develop.



ELECTRICAL REVIEW AND INDUSTRIAL ENGINEER



DANIEL H. BRAYMER
Editorial Director

Assisted by
G. A. VAN BRUNT E. H. HUBERT F. E. GOODING

Chicago, June, 1922

What's in Your Junk Pile?

SOMEWHERE around every works, perhaps in the repair shop, in the stock room or in the backyard, is a pile of miscellaneous materials and parts that the junk man looks at with envious eyes. Just what may or may not be in this pile of scrap is seldom known and it serves its best purpose when the repair man wants a piece of resistance wire, a short piece of angle iron or some other odd and end to use in an emergency. The older the pile and the more frequently it is added to, the greater grows the importance of knowing just what it contains.

In one large automobile plant the maintenance engineer has found that his junk pile is worth about $500,000 a year. This was discovered by studying how junk is handled as a commercial product. First from dealer to the yard, yard to the junk broker and broker to the junk user. It was found that a real market exists for classified junk that can be delivered in special assortments and that a large part of this $500,000 could be credited to the very act of knowing what the junk pile contains and sorting its contents into the grades for which there is a demand. The moral of all this is, then, if you can't eliminate this waste, find out how to turn it into its greatest cash value. Here is a chance for the maintenance department to set up a credit account against natural wear and tear, and even in those cases where maintenance costs may already be low a still better aspect will be given to the economies that the maintenance man is expected to work out.

How Often Do You Inspect Your Fuses?

INSPECTION reports on burn-outs of motors or other electrical equipment frequently contain the statement or inference that the damage would have been less, or perhaps the accident would not have happened, if the circuit had been properly fused. This usually means that fuses were originally installed in accordance with the regulations, but that when they blew out they were either replaced by fuses of much greater capacity than the originals, or by pieces of heavy wire or other conductor.

This practice is as old as the use of fuses, and it is easy to see how it comes about. An operator overloads or otherwise abuses a motor, and the fuse promptly blows out. Perhaps the trouble man is not within easy call, or the stock of new fuses may be exhausted, or the operator wishes to cover up his carelessness, so he replaces the useless fuse with a piece of conductor that may have greater current-carrying capacity than the line itself and considers that his troubles are over.

There is no doubt that the blowing of a fuse causes annoyance and delay, but it is equally true that such an occurrence is a danger signal and should be so regarded. Fuses are put in to protect electrical equipment—not for the purpose of training operators in self control and a little time spent in explaining this fact to workmen who may not understand it will do much to eliminate the expensive practice of overfusing.

Those who are in charge of maintenance work may not be able to prevent entirely this unauthorized tampering with fuses, but they can greatly lessen the chances of serious results by frequent inspections of all circuits to determine whether fuses of the proper sizes are being used. Heavy copper wire and large spikes may be excellent conductors, but their protective value against overloads is exceedingly small.

Are You Buying Metal or Reliability?

EVERY industrial man has at some time or other been confronted with the problem of defending his recommendation on the purchase of new equipment or supplies. One question that is frequently brought up relates to size. "Of course, you have a factor of safety or an extra allowance for emergencies, but can't that be 'shaved' some so that a smaller size or a smaller quantity will do?" is most likely familiar to everyone who has as a boss a man who desires to make sure that there is a fundamental reason for the expenditure. When it comes to a debate the shop man, who is more used to wrestling with shop problems, often loses out and agrees to accept something that his better judgment rejects.

One argument on factors of safety which an industrial man has used with success, runs about as follows: "Of course, we have a factor of safety; everything worth buying has a factor of safety. Why did you buy an A. B. C. car instead of an X. Y. Z.? Simply because when you start out for a ride you want to know that you will not only get there, but get back, and that there is enough factor of safety in construction to stand the punishment of a rough detour. It would not need such a factor if you were sure that the car would never get off smooth asphalt. But you know that a car is going to get rough going sometime, and I know that this equipment is going to be called upon sometime to deliver more than we should expect of it. I want equipment that will perform just as you expect your car to perform, for in neither case are we buying by the pound. We are buying *reliability* and we must include *that* in the purchase price, for a breakdown means more than the repair bill. In the case of the car, it means inconvenience to you, a broken engagement, a postponed journey, or perhaps even hardships. A break-

down in the plant means idle men, idle machinery, and in some cases (particularly with food or food products and chemical industries or processes) a loss of the product because the process cannot stop. In any case it means interruption of production and delivery. The repair bill here may be a trifling item, but the other losses due to unreliability are big."

When such an argument is supplemented with details from an investigation of the equipment, talks with users, studies of the literature describing several types and personal examinations of these types, your batting average on getting approvals on your recommendations will be high.

When Material Handling Costs Money

WHEN plants are not on full production schedules, too little attention is paid to material handling problems. Because of the low volume and close supervision, the work moves smoothly. When production increases, all available storage places are apt to become filled with trucks or tote boxes of parts-in-process, so that it is almost impossible to get at any group of parts when they are needed without having to move several other groups. Production then begins to slow up because the internal transportation system fails to keep up with the speed of the rest of the works.

It is under stress that the real need of a transportation system shows up. But when everything is in a jam there is but little time or opportunity to do constructive planning or try out new methods. "Everything is behind and cannot stop," says the manager, and he generally tries to force the inadequate methods through by added supervision of the truckers. This not only means increased cost, but it is only a makeshift—it does not cure, but only relieves temporarily. A study of the work done and the working conditions will disclose the solution. Just what is the best solution depends, of course, upon the problem, but there can be no better time to study conditions than when work is not so pressing but that there is time and opportunity to give it concentrated attention. Each month a solution of a particular material handling problem is contained in the "Handling Materials" department, beginning this month on page 306. Articles on methods used to analyze the industrial transportation problems, the equipment available, and some of the possible solutions, will appear in coming issues.

How Is Your Load Distributed?

A LOAD SURVEY of the motors in the average industrial plant which makes any extended use of electrical energy frequently ranks high as a dividend-paying proposition. Granting that all of the motors were properly loaded when they were installed, constant changes in the location of machines or in the nature of the product are the rule rather than the exception in most plants. These changes inevitably bring about many alterations in the load of the various motors. Consequently, unless this point is carefully watched, some motors are almost certain to be heavily overloaded while others will be carrying only a fraction of their rated capacity.

Both these conditions are undesirable and unnecessary. A motor which is too heavily overloaded is a distinct liability rather than an asset, while any considerable proportion of induction motors carrying loads much below their normal rating will result in a low power factor, with its attendant evils. In addition, they represent a certain amount of capital from which no return is yielded.

A load survey is neither difficult nor particularly expensive to make and when properly conducted will point out these weak spots. If advantage is taken of the information thus obtained, it is a comparatively simple matter to shift motors around until most, if not all, of them are loaded closely in accordance with their ratings. That means better service at minimum cost.

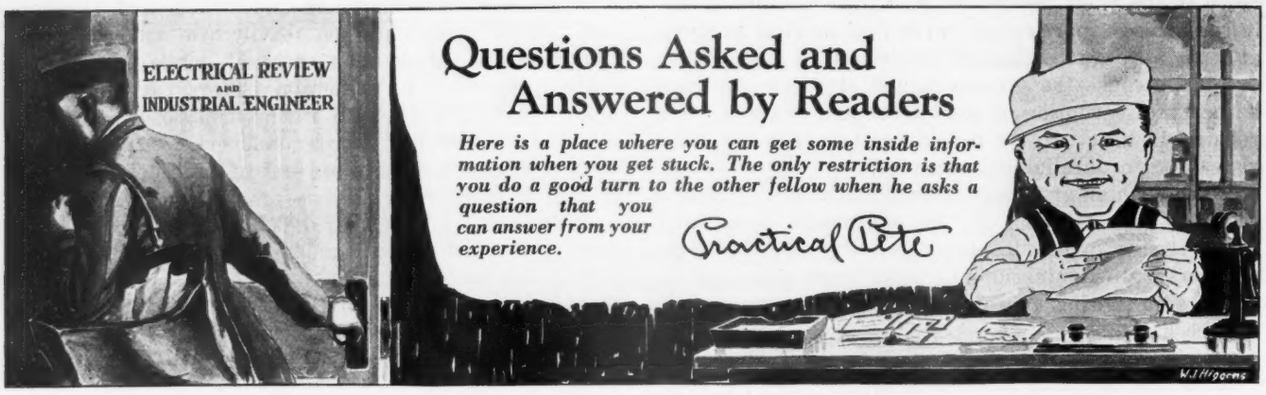
Still another important point which should not be overlooked is that the information which a thorough-going load survey will afford can be used to advantage when additional motors are to be purchased. A list of the motors available, together with accurate data on load conditions, will prevent the purchase of motors larger than service requirements demand. Without such information the opportunities for making expensive guesses are many.

Do You Work by Foresight or Hindsight?

MOST of us have a tendency to do our investigating, repairing and regretting after the damage has been done, to find that a fraction of the money and energy expended in this manner would have sufficed to prevent some if not all of the trouble. In the nature of things, hindsight is always more accurate and more easily applied than foresight, but the latter is a great deal more valuable. Nor is foresight the mysterious and uncanny ability to look into the future that it is sometimes taken to be. At bottom it consists essentially in carefully analyzing the present situation and then, largely on the basis of past experience, reasoning out the most probable course of events in the future. When that is done it is a fairly easy matter to plan a course of action.

The application of these principles to maintenance work will bring results far exceeding in value the time and effort required to produce them. Maintenance should involve much more than detecting hot bearings or measuring air gaps. The electrical system in every industrial plant has its weak spots, certain pieces of equipment which are more likely than others to give trouble. Likewise, one or more machines, or even one or more departments, may be particularly important, in that they occupy such a position with respect to the rest of the plant that any failure or mishap there may interfere very seriously with operations throughout the plant. In such an instance foresight would consist not only in the recognition of such conditions and the exercise of every precaution to prevent failure, but also in the formulation in advance of plans to minimize the effect of any mishaps which might occur. Naturally, this involves holding extra parts or equipment ready for instant use and deciding just what should be done, and how, to meet any emergency.

Foresight does not necessarily mean borrowing trouble, but it does mean realizing that trouble may occur and getting ready to meet it.


ELECTRICAL REVIEW
AND
INDUSTRIAL ENGINEER
Questions Asked and Answered by Readers
Here is a place where you can get some inside information when you get stuck. The only restriction is that you do a good turn to the other fellow when he asks a question that you can answer from your experience.
Practical Pete
W.J. Higgins

Who Can Answer These?

Making Fiber Wedges.—If some repair man will tell me a good way to cut good slot wedges from fiber and how they can be beveled, I will be most grateful.
Memphis, Tenn. C. L. M.

* * * *

Changing Connections of Compensator.—How can a two-phase compensator be changed so that it can be used with a three-phase motor?
Baltimore, Md. R. D.

* * * *

Wiring for Motors.—In the article by H. L. Cornelison of the March issue on page 129, third column, Mr. Cornelison states that the National Electrical Code permits rubber covered wire to carry the same current as wire with other insulations providing the circuit feeds only one motor. I cannot find anywhere in the Code where permission is given to wire up to the capacity of Table C. Would you kindly explain how to use Table C and Table A of the Code when wiring for one motor and also when wiring for two or more motors?
Yonkers, N. Y. A. C. B.

* * * *

Why Does Polyphase Generator Heat When Operating Single Phase?—Why is it that the rotating field structure in a polyphase turbo-generator heats excessively when running single-phase and how does the pulsating flux occur at double frequency? Perhaps, if the answer to this is shown in detail by current, flux and the incident e.m.f. curves plotted in their proper relations, the solution would be plain.
Patchogue, N. Y. H. M.

* * * *

Grounding of Squirrel-Cage Rotor Bars.—I would like to have someone answer the following questions: Why will some squirrel-cage rotors run when the bars are grounded solid in the core and others if grounded only slightly, maybe one or two bars, will burn and heat or lose power? I, myself, have hammered the laminations in to ground the bars where they could not be reinsulated. I have also grounded the end rings solid after perfectly reinsulating the bars, yet grounding a couple of those bars would impair the efficiency.
Philadelphia, Pa. G. W. H.

* * * *

Cutter for Making Large Holes in Switchboard Panels.—I would like to see a description of a boring device that has been found successful for cutting holes about 4 to 8 in. in diameter in slate switchboard panels.
Quincy, Mass. T. M. C.

* * * *

Connecting A. C. Generator as a Motor.—We have a 30-kva., 240-volt, three-phase, 60-cycle, revolving-field, two-slip-ring, separately-excited generator which we wish to use as a motor. Could we make it self-starting by installing a double-throw, double-pole, switch across the exciter, to short-circuit the rings until up to speed and then throw in the exciter?
Richmond, Va. H. K. B.

* * * *

Changing 220-volt Motor for Operation on 440 volts.—We have a 10-hp., 220-volt, three-phase, 60-cycle motor which operates at 1,800 r. p. m. It has 72 slots, 36 coils with a throw of 1 to 18. The coils are wound with 12 turns of No. 15 D. C. C. wire. The connection is single-star. In order to operate this motor with a single-star connection on 440 volts at a speed of 1,200 r. p. m. would a winding with coils of 30 turns of No. 17 D. C. C. wire and a throw of 1 to 12 be satisfactory?
Wilmington, Del. I. A.

* * * *

Shifting Brushes of Motor.—In the case of a 3-hp., d. c., shunt-wound, 220-volt motor that operates at 1,700 r.p.m., by shifting the brushes a little against the speed of rotation about 1,720 r.p.m. can be obtained. Will someone please explain why this causes an increase in speed and if the horsepower of the motor is reduced thereby?
Chicago, Ill. J. A. L.

* * * *

Oil on Generator Commutator.—We are having trouble with oil working onto the commutator of a 16-kw. d. c. generator. The bearing is run with the oil as low as possible, but still a little gets past. I would appreciate details of a method to stop this.
Alta, Canada. W. S.

Answers Received To Questions Asked

Repairing Battery Plates.—I would like to know if there is some way by which bent battery plates can be straightened and used again.
Gary, Ind. L. C. W.

Lead plates that have become buckled when discharging or by a long extended overcharge may be placed between two 7/8-inch hardwood boards and clamped tightly in a vise. If some of the plates are pasted, cracks may start and allow the paste to fall out. It is not advisable for a man without considerable battery experience to attempt to repair plates. New ones can be purchased from a nearby service station.
New Britain, Conn. H. S. Rich.

* * * *

Proper Temperature for Pouring Babbitt.—When pouring babbitt what inexpensive but accurate method can be used to tell when the metal is at the right temperature? Some people judge this temperature by inserting a pine stick in the babbitt. When the stick begins to char the metal has become hot enough. I have heard that this method is not accurate.
Butte, Mont. A. H. E.

The writer knows of no inexpensive method to determine the correct temperature to which babbitt should be heated for the simple reason that different babbitts require different heating. A lead-base babbit can be heated to a higher degree than a copper, nickel, aluminum-hardened babbitt or a tin-base babbitt. A cheap babbitt may be heated real hot and the bearing poured and probably as good a result obtained from this bearing as could be expected with that price of babbitt. However, the higher priced babbitts, if heated to the same extent, would be burned and results naturally expected from this high priced babbitt would not be obtained.

A soft pine stick is used extensively in practice in the ordinary repair department, but good results depend upon the skill of the operator who should know the type of babbitt he is pouring. This method is in reality a method of touch. As the pine stick is inserted in the moulten metal, there is a feel as though bubbles were occurring along the length of the inserted stick. The rapidity of this action is an indication of the extent of heat of the metal. Consequently when an operator has used a certain type of metal extensively and has observed the results secured from a number of pourings of this metal, he judges the correct heat from the results he has obtained. With an entirely new metal of a different type he may be considerably off upon the first few pourings. The writer thinks it haphazard at best.

Whenever possible use a pyrometer in the babbitt melting pot. A metal may easily be heated above 850 deg. F. without the operator being aware of it. Eight hundred and fifty to nine hundred is the usual pouring heat. Do not heat above 900 deg. F. The main object in melting babbitt is to have it flow into all of the recesses of a mold. As that mold happens to be a bearing the babbitt should be heated just enough to run easily into all parts. Do not heat until the metal oxidizes or volatilizes.

Gary, Ind. A. L. GEAR.

* * * *

Connections for Two D. C. Series-Wound Crane Motors.—We have a traveling crane operated by two d. c. series motors connected in series on 220 volts. These motors recently burned out and were sent outside for rewinding. The shop rewound them for 220 volts instead of 110 volts and refuses to make the job right. We do not want to rewind them if they can be connected as they are. The controller layout will permit me to wire the motors so that the field coils are in series and the armatures in parallel without changes. I would like to know if there is any reason why this connection will not work.

Would it be better to operate the motors in parallel with additional resistance inserted in the field coil circuits so that they can be connected in parallel also?

Owosso, Mich. J. E. P.

The quickest and best way out would be to rewind the field coils of each motor with twice the number of turns and half the size wire. On the other hand, if the proper amount of resistance is inserted in series with each field and each motor is connected across a 220-volt line, then they should operate O. K., as the conditions are practically the same.

To put the fields in series and each armature across the line, is out of the question.

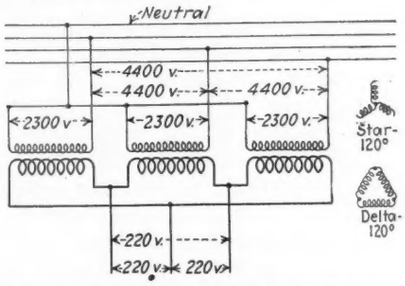
Detroit, Mich. A. C. ROE.

* * * *

Transformer Connections.—In the case of a three-phase, four-wire, 4400-volt distribution circuit with grounded neutral, please show the proper transformer connections and how the transformer coils are connected. Are the three phases 120 electrical degrees apart and should the secondary be grounded?

Ontario, Canada. P. R.

The connections of a three-phase, four-wire, grounded-neutral, 4,400-volt distribution circuit are as shown in the accompanying drawing. Where it is necessary to maintain three-phase secondary voltage transformers with primary ratings of 2,300 volts can be used, connecting the primary in star and the secondary in delta. The phases will be 120 degrees apart both on primary and secondary.



Connection for three-phase four-wire 4,400-volt primary circuit.

The secondaries should in all cases be grounded, in fact the National Electrical Code requires this.

A single-phase load can be fed from this system by connecting the 2,300-volt side of a transformer across one phase wire and the neutral. The secondary must be grounded. If it is a three-wire secondary, the neutral wire must be grounded; if two-wire, one of the two must be grounded.

Galva, Ill. C. W. ROSELLE.

* * * *

Changing Speed of D. C. and A. C. Motors.—Please explain a practical method of increasing the speed of a. c. and d. c. motors about 20 per cent without rewinding them. I would like to know the principles involved in figuring out these changes in each case.

Alton, Fla. L. H. H.

In the case of the d. c. motors the speed can be increased to some extent by weakening the field of the motor. This can be done by inserting resistance in the field circuit. The principle involved is that the weakening of the field requires that the armature revolve at a higher speed before a counter e.m.f. is produced sufficient to balance the e.m.f. of the line. It might not be practical to get 20 per cent increase but it can be easily tried out.

Omaha, Nebr. A. G. KNIGHT.

* * * *

The speed of direct-current motors can be increased by putting a regular rheostat in series with the shunt field. Do not increase the speed more than 50 per cent, because excessive sparking will result. Have the rheostat about the same resistance as the field itself.

The speed of alternating-current motors cannot be increased without rewinding or increasing the frequency of the supply.

Boston, Mass. EDWARD A. GIBBS.

* * * *

Winding for Bell Ringing Transformer and Demagnetizing Hand Tools.—Here are two questions I would like to have answered by readers:

(1) What changes must be made in the winding of a 60-cycle bell ringing transformer for use on a 25-cycle circuit? The present winding is 1000 turns of No. 20 B & S and 100 turns of No. 14 wire. The rating is 100 watts, 110-volt primary, 10-volt secondary.

(2) In our factory tool grinders with magnetic chucks cause considerable annoyance to mechanics by magnetizing their tools, such as calipers, and the like. Please explain a simple method for demagnetizing these tools.

Brooklyn, N. Y. A. D.

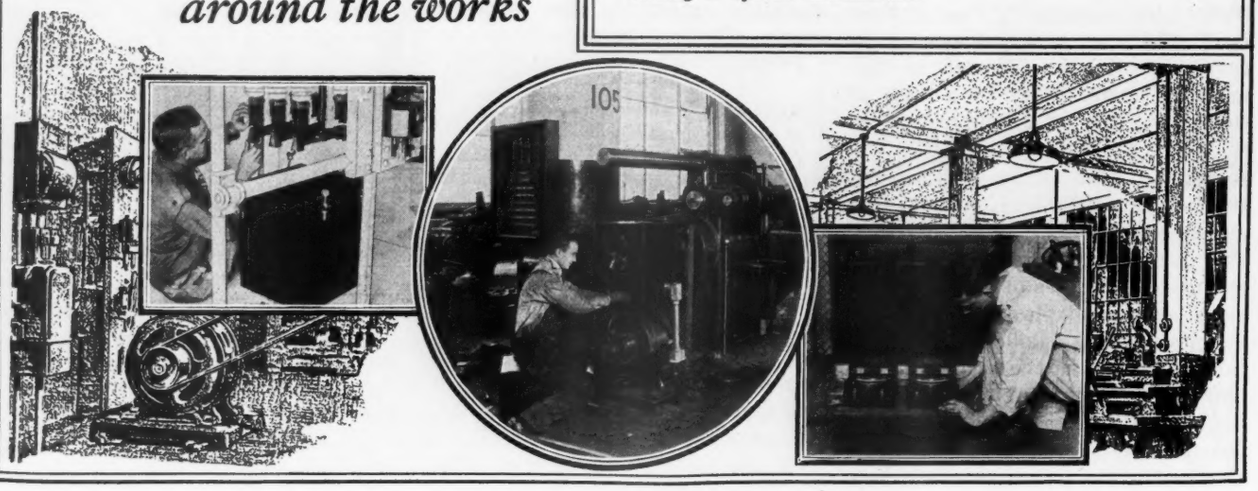
(1) I should think that it would be satisfactory to rewind your transformer with about 2,000 turns of No. 23 B & S on the primary and 200 turns of No. 17 B & S on the secondary for 25-cycle operation. This could not be determined accurately without more definite information and calculation.

(2) To demagnetize your watches and tools, wind a coil about 3 in. long and 4 in. in diameter with about 2,000 turns of No. 20 wire and energize with 25-cycle supply. Use a small lamp-bank, about six 50-watt, parallel-connected lamps, or some other resistance, in series with the coil. Pass the articles which are to be demagnetized slowly through the coil several times, with the current turned on. Use as little current as possible by adjusting the resistance.

Boston, Mass. EDWARD A. GIBBS.

SERVICE
around the works

For this section ideas and practical methods devised to meet particular operating conditions are invited from readers. The items may refer to inspection, overhauling, testing or special installations.



Ordinary Forty-Five Degree Pipe Fittings Save Time on Installation Job

IN the installation of a 15-hp., three-phase, 220-volt motor for driving a pressure blower and a gas pump, the shape of the motor foundation and the location of the starting switch on a near-by wall made changes of direction essential in running the motor leads. Three No. 6 rubber-covered wires were run to the

In an emergency ordinary pipe fittings were used in the conduit line to this motor.

motor in 1¼-in. galvanized-iron straight conduit. No fittings suitable for bends were at hand or within easy reach and in order to save time ordinary 45-deg. pipe fittings were used successfully. By this simple arrangement the motor lead-wire conduit was carried from the starter downward and beneath the plant floor, across and below the removable planking shown in the illustration, and thence on a 45-deg. diagonal run upward to the motor, where another 45-deg. turn carried the leads into the motor bushing fitting. In addition to avoiding delay, the cost was small in proportion to the length of piping involved.

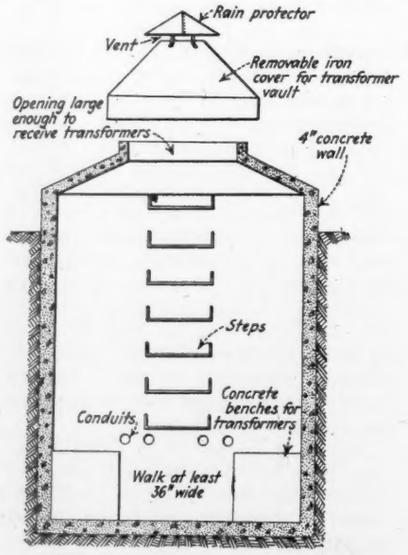
Broken Short-Circuiting Ring Cause of Trouble in Control Magnets

AN UNUSUAL case of trouble, the cause for which could not readily be determined, occurred recently with one of the alternating-current control magnets used for starting a hoist motor in the works of the Miami Copper Company. The armature would be drawn toward the face of the magnet, but instead of holding the contacts together would chatter continuously. Other magnets on the same panel did not show this trouble. After replacing the magnet with a spare unit it was found that the short-circuiting ring that is embedded in the face of the magnet was broken at a point within the laminations. When this was repaired the magnet operated satisfactorily.

J. J. LUCHESSA.
Chief Electrician,
Miami Copper Company,
Miami, Ariz.

How Rubber-Covered Wire and Conduit Saved Cost in Underground Installation

DUE to frequent reconstruction of the buildings and equipment at the Casper, Wyo., plant of the Midwest Refining Co., it was found desirable to place underground the distribution lines supplying the plant. It was necessary, however, to allow for changes from time to time which would require the reconstruction and rerouting of even underground distribution. Therefore,



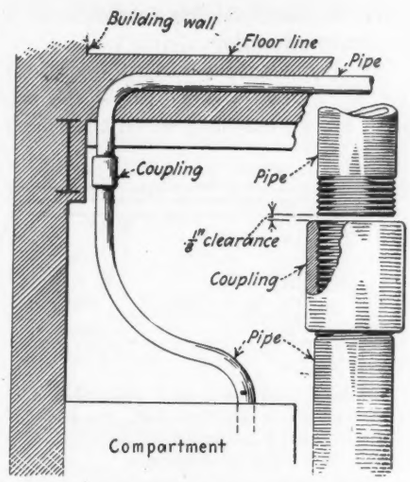
Details of concrete vaults housing transformers for an underground distribution system.

in order to keep the cost of the construction as low as possible it was decided to install rubber covered

wire in ordinary conduit as this could be easily removed and the material salvaged.

About 2,000 ft. of black-enameled conduit were laid and sealed at the joints with shellac. The joints were also encased in concrete to reinforce the pipe in case it settled in soft earth. Concrete man-holes for pull boxes were placed every 200 to 300 ft. which gave a reasonable length of run between boxes. These pull boxes are about 4 ft. square on the inside to give sufficient room to work in. Distribution was made from underground concrete vaults, as shown in the accompanying sketch, constructed with shelves on each side on which the transformers were placed with space enough between to allow sufficient room for working in safety. Permanent steps are placed in the forms before the concrete hardens. The location of these vaults was determined by plant conditions. Most of the pull boxes and vaults have galvanized-iron covers with open ventilating tops and rain shields. These keep the boxes and vaults dry, yet permit circulation of air through the conduits to prevent the collection of moisture. These tops are removable and cover an opening large enough to permit the handling of transformers into and out of the vaults by means of a tripod and hoist.

In any case where it is necessary for traffic to pass over the boxes or vaults, a flat, removable top or manhole cover is used and a pipe run underground to a ventilated opening in the nearest safe place. Ventilation is better if the ceiling of the vault slopes up to the ventilator as the heat generated by the transformers escapes more readily. The size of the transformer benches depends upon the size of the transformer to be used. Ordinary pole-type transformers are used in this installation and have not given any trouble from heating. Air line switches placed at the outgoing side of the vault permit of cutting out line away from the source in case of trouble. The conduits enter from the end of the vault and the lines are carried exposed on cleats inside the vault to the transformers. The dimensions of the vaults and openings are determined by the size and number of transformers used. The only fixed dimensions are at least a 4-in. concrete wall and a 36-in. walk between the transformer benches.



When bent pipes must be joined, why not do it this way?

By screwing the coupling full length on one pipe and then screwing it back on the other when they are brought together, one man is able to connect up bent pipe in corners or near a wall.

Since the first line was installed it has been removed several times with but little pipe lost and all of the wire saved. One feeder which has been down for over a year has given no trouble.

Chief Electrician, The Midwest Refining Co., Casper, Wyo. H. B. SHERWOOD.

How to Couple Bent Pipes in Out-of-the-Way Corners

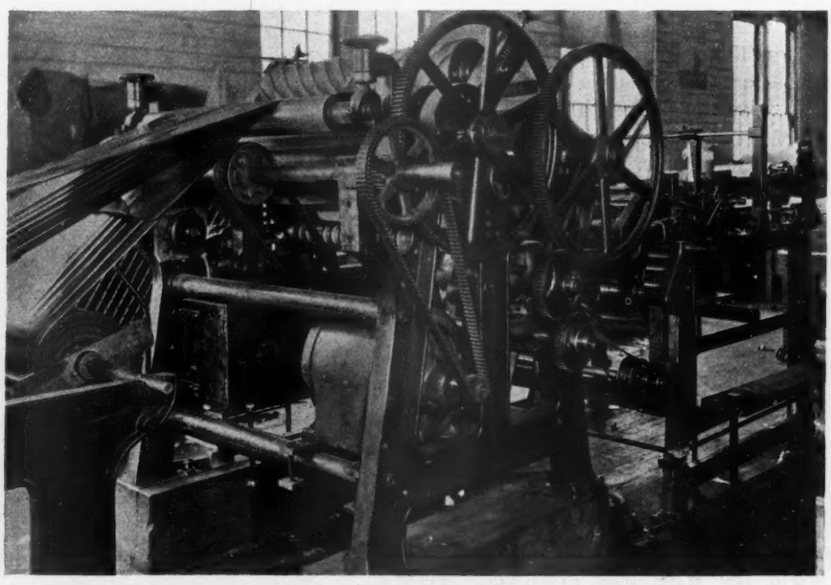
WHEN large bent pipes are to be joined together, the conditions on the job frequently do not allow either one of the bent pipes to be screwed into the coupling, and it may not be desired to use a union. Before installing pipes such as shown in the illustration, one construction man threads the ends of these pipes far enough to allow the coupling to be screwed completely onto the pipe as shown in the enlarged view. When the pipes are installed in their respective places the coupling is screwed back onto the other pipe. A similar method may also be used when placing bent conduit in corners or other out-of-the-way places.

New York City FRANK HARAZIM.

Mounting Motor Inside of Machine Saves Aisle-Space

TO SAVE space, a 3-hp., 220-volt, direct current motor in the factory of the Springfield Glazed Paper Co., Springfield, Mass., was mounted inside the frame of a 40-in. Hamblet rotary cutter, as shown in the accompanying illustration. It was originally proposed to locate the motor at the side of the machine, in the aisle space, but it was found feasible to mount it upon two flat bar straps clamped by bolts to the horizontal cross-piping members shown. A Link-Belt silent-chain drive from the motor pinion to the main driving shaft satisfactorily takes care of the short driving connection. This more convenient arrangement leaves the space around the cutter free for other uses. This motor is operated with push-button control and the contactors are mounted inside the frame in the box shown at the left, a further economy in space. Both the motor and contactor box are easily accessible even when the machine is in operation.

This motor is easily accessible and does not occupy space which could be used for other purposes.



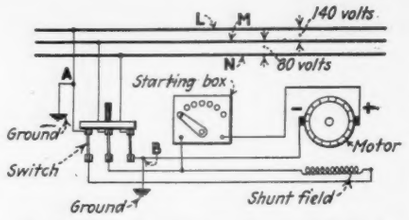
Repeated Reversals of Armature Rotation Due to Open and Grounded Field Lead

IN A local manufacturing plant a small shunt-wound motor is geared to a mixing apparatus which revolves at a very low speed. Current is supplied for the plant at 220 volts, but in order to secure a comparatively low speed of rotation, the motor is wired so as to impress only 80 volts across the armature terminals, while the remaining 140 volts send the current through the field coils.

One day the man who operates the mixing machine reported that it had suddenly started to run the wrong way, and to his certain knowledge no one had been meddling with either the machine or the motor that drives it. When the engineer came to investigate he found the motor running the right way. The operator was surprised, but maintained that the machine had really been running wrong way about. In a short time the motor emitted a flash from the brushes, stopped for an instant, and immediately began turning in the wrong direction. After running this way for a few minutes there was another sputter at the brushes, the armature came to a standstill, and then promptly resumed rotation in the right direction.

The motor is wired as shown in the accompanying diagram. The field winding is connected across the main lines *L* and *M*, between which there is a difference of potential of 140 volts. The armature winding is connected across the main lines *M* and *N*, which have a potential difference of 80 volts. An investigation showed that the lead to the field coils was broken at about the point *A* and that vibration had caused a grounding of the wire on a neighboring water pipe, with intermittent contact between the broken ends. It was also discovered that the connection between line *N* and the armature was grounded at about the point *B*. The normal current-flow in the field winding, due to contact between the broken ends of the lead wire, was from line *L* to line *M*, since line *M* has a negative relation to line *L*. But when the broken field wire was grounded, the current flow was from line *M* through the field coils and ground, as indicated by the dotted line, to line *N*, since line *M* has a positive relation to line *N*. Hence, when the wire was grounded, the current traversed the field coils in a contrary direction.

If the armature circuit had been properly protected by fuses, the excess of current-flow, when the speed



A field lead open and grounded at *A* and an armature lead grounded at *B* caused intermittent reversal of the direction of rotation.

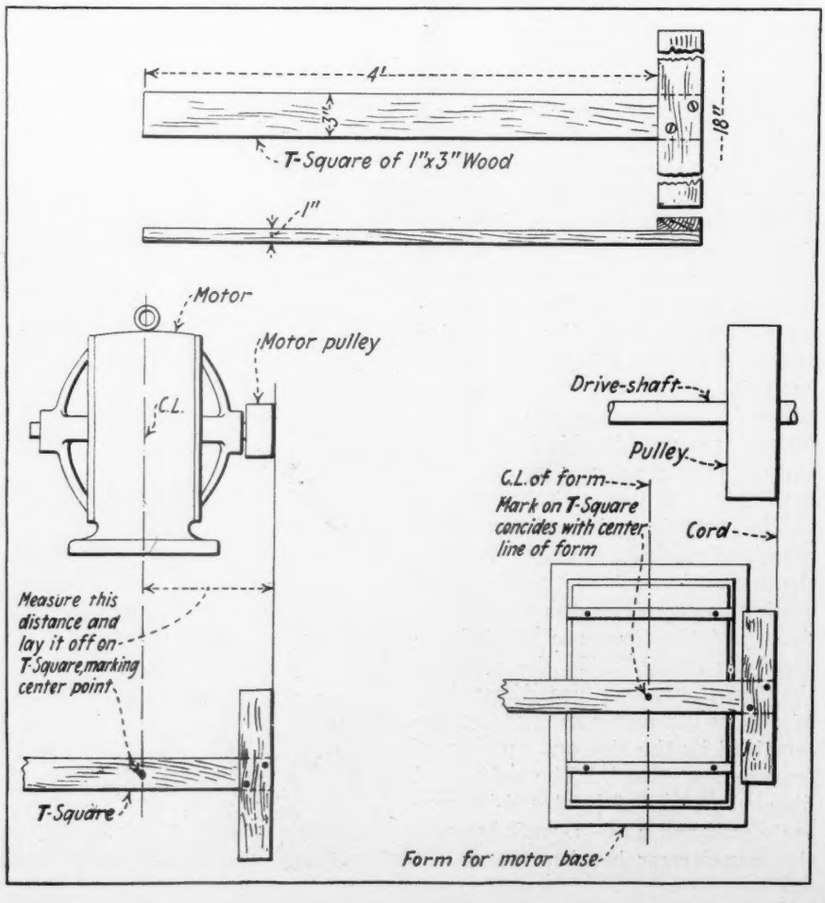
of the armature diminished the first time the field was reversed, would have blown the fuses and the motor would have stopped. The first fuses in the circuit had blown and been replaced with heavy copper wire.

St. Louis, Mo. A. J. DIXON.

How a T-Square Can Be Used to Line Up Motor Foundations

WHEN making a foundation for a motor, it is sometimes difficult to get it lined up so that the motor pulleys and the pulley on the driven shaft or machine will come directly in line. For a job like this, the writer has found that an easily constructed T-square is a great help. This T-square is made of wood about 3 in. by 1 in. in size. As shown in the drawing, the long portion of the square is 4 ft. in length and the end is 18 in. long. To use this T-square, place one end of it opposite to the end of the motor as shown in the drawing. When it is in this position, mark on the T-square the point which comes opposite the center line of the motor. This is the correct way to proceed if the two pulleys are of the same width. If the driven pulley is wider than the motor pulley, add to this distance which is marked on the T-square, one-half the difference between the widths of the two pulleys. After this point is marked, take a cord or plumb line and stretch it across the end of the driven pulley and down to the point where the foundation will be located. Then place the T-square so that the cord touches the entire length of the end of the T as shown. The mark on the T-square will then indicate where the center line of the motor

The base form is shifted until the end of the T-square and the edge of the driven pulley are parallel.



foundation should be. From this line the positions of the base bolts may be easily located.

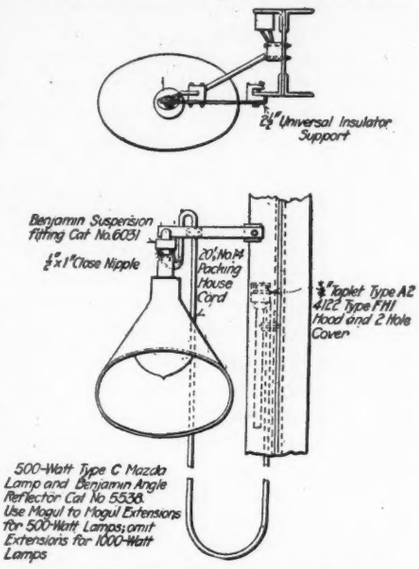
The drawing shows a wooden form which has been built for pouring a concrete foundation for a motor. In this case, the T-square is laid on top of the form while the form is shifted until it is in the correct position. If the driven pulley is higher or lower than the motor pulley will be, place the square at an angle by inserting a couple of wedges between the top of the form and the T-square. By placing the square at an angle in this manner, the string can be made to touch the full length of the end.

The writer has found this T-square also to be very handy when hanging motors from the ceiling. When marking the square, additional marks are made upon it for the base bolts of the motor and these marks are transferred directly to the ceiling. Sometimes there is no pulley on the driven shaft before the motor is put in place. In this case it is necessary to get the cord square with the driven shaft. In order to do this, another T-square may be placed on the shaft, with its long side pressing against the edge of the shaft. This will insure that the line from the shaft to the motor makes a right angle with the shaft. J. JENSEN.

Chief Electrician,
Dominion Oilcloth & Linoleum Company,
Montreal, Canada.

Adjustable Industrial Lighting Fixture

LIGHTING unit illustrated below may be raised or lowered on its support, or even detached for use as a portable extension lamp. It is held on the flange of a structural-steel column by means of a strap-iron arm bolted to a universal 2½-in. insulator support. By loosening the bolt in the insulator support the lamp may be raised to any desired height, or may be detached altogether and transported to any nearby work where it may be required. The lamp is enclosed in a Benjamin angle reflector No. 5,537 and hung on the end of the arm by means of a Benjamin suspension fitting No. 6,031. Mogul extensions are used for 500-watt lamps, but no extension is required with 1,000-watt lamps Electrical connection is made through 20 ft. of flexible No. 14 packing-house cord.


2½" Universal Insulator Support
Benjamin Suspension Fitting Cat No.6031
½"x1" Close Nipple
20' No.14 Packing House Cord
½" Toplet Type A2 4122 Type FMI Hood and 2 Hole Cover
500-Watt Type C Mazda Lamp and Benjamin Angle Reflector Cat No 5538. Use Mogul to Mogul Extensions for 500-Watt Lamps; omit Extensions for 1000-Watt Lamps

Lamp may be adjusted to any height or detached for use as a portable light.

How a Direct-Drive for Copping Machines Saved Aisle-Space

SPACE is saved and the aisles are kept clear at the New Bedford, Mass., factory of the National Spun Silk Company, Inc., by the installation of direct-drive motors for the operation of copping machines, as shown in the accompanying illustration which contains examples of both the old and new methods of driving. In the old arrangement, shown on all but the first machine, a 3-hp. motor running at 1,730 r. p. m. with silent chain drive was used to operate seven No. 90 Universal copping machines. To get the required distance between the motor and the shaft on the machines it was necessary for the motor to project into the aisle between machines about ten inches. This was not only inconvenient but the motor constituted a tripping hazard.

In the new arrangement, the 3-hp. motor is mounted on a special frame which lines the motor shaft up with the main driving shafts of the seven adjacent machines and leaves a clear aisle as is shown on the first machine in the illustration. The absence of belt or chain simplifies the construction.

The pulleys and belt carried in the galvanized-iron housing on the right of the motor shown on the first machine is incidental to speed reductions within the copping machines and is not associated directly with the driving motor, as might appear from the illustration. The Westinghouse, three-phase, 550-volt, direct-connected motors run at 1,760 revolutions per minute.

Direct drive saves ten inches of aisle-space.

The machine in the foreground is direct connected. Those at the rear are driven by a silent chain, making it necessary for the motor to project out into the aisle. Sheet metal plates on the floor catch oil drippings from the motor.

Safety of Motor Equipment Menaced by Lax Methods of Installation

TEMPORARY installations of electrical equipment for any purpose should be put in as carefully as those designed for permanent service. Also, the use of common transmission lines for conveying current from separate sources to the armature or field coils of two or more motors should be carefully avoided. The reasons for this were shown recently by a mishap that nearly ruined a 300-kw. polyphase synchronous motor. The d. c. dynamo that supplies the 220-volt exciting current for this motor is belted to the motor shaft. The motor is self-starting; that is, with the field unexcited, the armature is thrown onto the supply mains. When the machine attains synchronous speed, the field circuit is closed and load gradually put on.

A 220-volt direct-current motor had been installed temporarily for driving a rig used in reboring the cylinders of one of the engines in the plant. As a matter of convenience in wiring this motor, the positive side of the circuit was connected to the positive field-terminal of the synchronous motor, while the positive lead from the main 220-volt direct-current busbar was connected to a terminal of the field switch on the positive side of the exciter circuit, as in the accompanying diagram.

Inasmuch as the 220-volt motor was only a temporary installation, no especial precautions were taken in the insulation and it was heavily grounded on the positive side. The exciter circuit of the synchronous motor was likewise grounded on the positive side, as shown.

One morning the synchronous motor was started as usual with the field circuit open; this was closed when the machine reached synchronous speed. At the same time the circuit of the direct-current motor driving the boring rig was closed. When the engineer attempted to adjust the power factor, by means of the rheostat in the exciter circuit, the ammeter did not respond. In a few moments a very strong odor of burning insulation was noticed and it was found that the synchronous motor was so hot that the insulating compound was dripping from the field coils. The direct-current motor, too, was manifesting symptoms of distress. The engineer promptly pulled the line and field switches of the alternating-current motor, thus opening the circuits to both machines.

A search for the trouble finally disclosed the two grounds. They had short-circuited both the starting rheostat of the direct-current motor and the field rheostat of the synchronous motor, with the result that a very heavy current was traversing both the field winding of the synchronous motor and the armature winding of the direct-current motor. The field winding of the former was indirectly in circuit between the main positive busbar and the negative terminal of the exciter, while the armature of the direct-current motor was thrown, through the ground, between the positive terminal of the exciter and the main negative busbar.

If the circuits had been properly fused the accident could not have occurred. But there was only one fuse in the field circuit of the alternating-current motor, and no protective devices at all in the circuit of the direct-current motor. The fuse in the field circuit, being located between the ground on this circuit and the point of connection of the lead from the main busbar, was short-circuited and could interpose no protection.

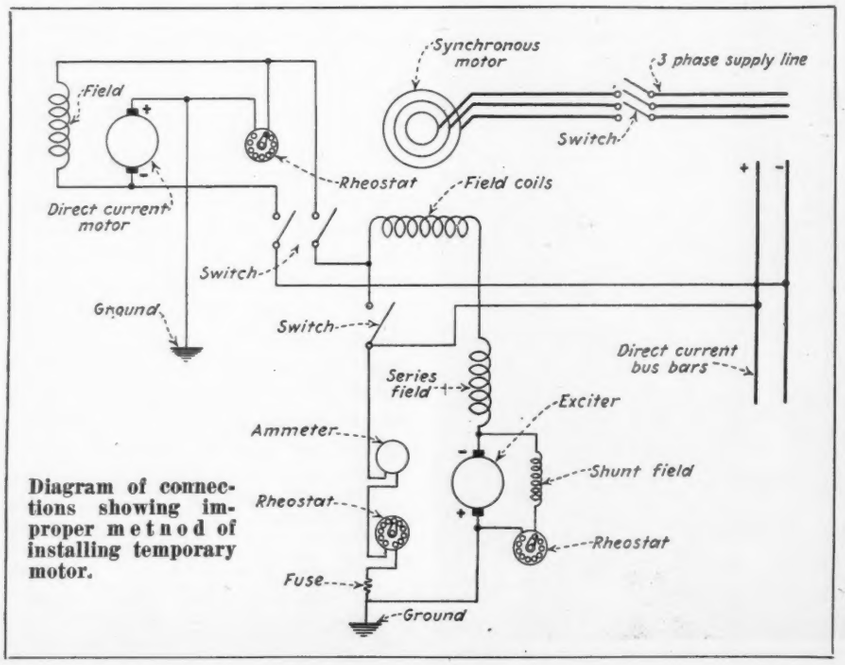


Diagram of connections showing improper metnod of installing temporary motor.

Steel Messenger Wire Supports Cables in Factory Substation

UNDER the above heading, a short article appeared on page 246 of the May number of the ELECTRICAL REVIEW AND INDUSTRIAL ENGINEER, describing a method of supporting cables in a factory substation in Springfield, Mass. It is questionable if the method shown is an improvement over the usual method of attaching the cables to insulators attached to the ceiling of the station at short intervals. Because, if the messenger wire should be broken by any means it would let the whole length of cable drop instead of only a few feet of it as would be the case if it were supported at closer intervals. While a broken messenger is something that might never happen, yet there is a chance of such an accident.

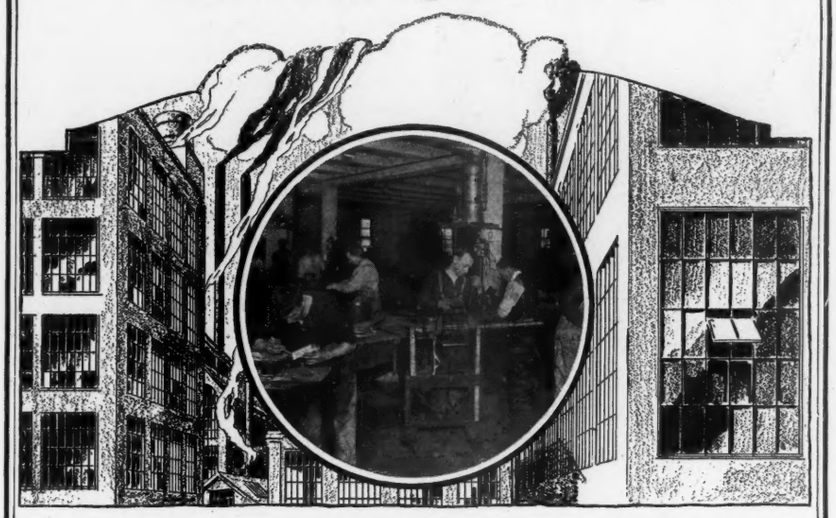
Furthermore, it is doubtful if the practice described is in accordance with the insurance rules of the National Board of Fire Underwriters, as their rules state:

"Wires must be rigidly supported on non-combustible, non-absorptive insulators, which will separate the wires from each other and from the surface wired over. . . ."

"Rigid supporting requires under ordinary conditions, where wiring along flat surfaces, supports every four and one-half feet, . . . In buildings of mill construction, mains of not less than No. 8 B. & S. gage where not liable to be disturbed, may be separated about six inches, and run from timber to timber, not breaking around, and may be supported to each timber only."

Westfield, N. J. G. H. MCKELWAY.

In the Repair Shop



This section is devoted to all sorts of electrical repair work, large and small. Special attention is given to tools found convenient at the shop bench and short cuts or improved methods. Articles on these subjects are always welcome.

Dual-Purpose Equipment Simplifies Repair Work

MANY repair shops find it necessary to get along with a small amount of well-chosen equipment. In such cases it is essential to get equipment which has the widest usefulness. One such piece of equipment which has been found useful by a number of repairmen is shown in the accompanying illustration. This bench drilling stand is fastened to the bench so that it can be used as an ordinary sensitive drill. The drill, however, can be swung in a complete circle so that it may be used for drilling the end of long shafts, as it is shown here, or other similar work which is too long to get under the bench drill. An extra long feed-lever gives a feed ratio of six to one.

This drill stand is bolted to the bench by four lag screws. It has six threaded holes in the base which can be used with half-inch studs and clamps to hold work in place while drilling. A portable electric drill, which may be attached or detached quickly, is used with this device. This portable electric drill will take drills from ⅜ in. to ⅞ in. in diameter. When required, the drill may be detached and used about the plant for other installation or repair work, which gives a greater range of usefulness to the equipment than if the drill could be used only on the bench.

This bench drill stand permits long parts to be supported on the floor.
The portable electric drill, which forms a part of the equipment, may be detached quickly and used around the plant for any miscellaneous installation or repair work.

Size of Electrodes Affects Deposition of Metal in Arc-Welding

THE size of the electrodes used in arc-welding should be such that the current in them is about 8,000 amperes per square in. If the electrodes are too large the arc is harder to maintain, the rate of deposition is slower, and the penetration is excessive. If the electrodes are too small they are fused too rapidly, with the result that the metal is deposited before the parent metal is fused, causing poor penetration and large overlap. In extreme cases the electrode may melt and drops fall on the parent metal, causing beading. The proportions between the size of the electrodes and the current density for the best results on work of average size is 90 to 125 amperes for ⅛-in. electrodes and 150 to 200 amperes for 3/16-in. electrodes.

San Jose, Cal. D. N. LOUIS.

Ammeter Plug Box Speeds Up Testing of Heating Units

IN THE testing of heating units, such as are used in ovens, incubators, and so on, considerable time was formerly lost in waiting for the unit to warm up so that the current reading would become constant. Connecting up a number of units at once to allow them to warm up saved part of this time, but there was still some loss in changing the connections so as to include the ammeter in the circuit. The writer therefore arranged an ammeter plug box as shown in the accompanying illustration, to which three units may be connected at a time, and the ammeter quickly plugged into any one of the three circuits.

The box is provided with three pairs of binding posts for the three circuits, as shown in Fig. 1, and three sockets for the ammeter plug, which is shown here inserted in one of the sockets. The ammeter plug

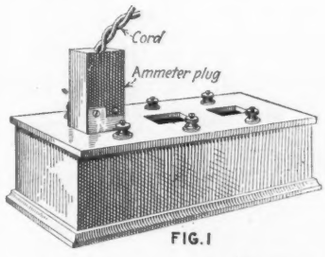


FIG. 1

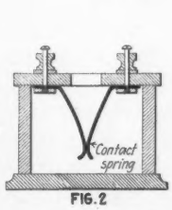


FIG. 2

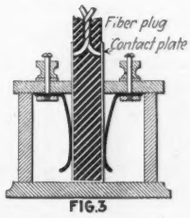


FIG. 3

This ammeter plug box saves time in testing heating units.
Three heating units are connected up at a time. As each unit is tested it is replaced by another, which will be ready by the time the other two are tested. The plug permits the tester to take the ammeter reading without disconnecting the wires.

is a block of heavy fiber with a brass contact plate on each side; these are connected to the ammeter terminals by means of a flexible cord. As indicated in Fig. 2, the binding posts are attached to heavy springs inside the box, which are normally in contact. On inserting the plug, the springs are separated but press against the contact plates on the plug as shown in Fig. 3, thus throwing the ammeter in the circuit. There is no break in the circuit while the plug is being inserted, and consequently no sparking or arcing.

Three circuits have been found sufficient for our work, for a given unit will reach a constant temperature by the time the other two have been read, the readings recorded, and the units replaced. The process thus becomes a continuous one, and no time is wasted in waiting, or in changing connections.

Central Scientific Co., Chicago, Ill. W. H. FARR.

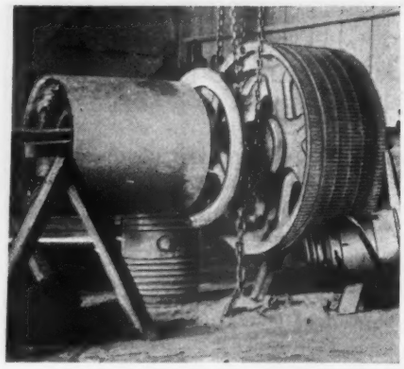
Wooden Rack for Storing Spare Pulleys

A WOODEN rack that can be cheaply and easily made in the shop has been found to be an ideal method for storing pulleys not in use. When the plleys are placed in the rack, their diameter, bore and face sizes are painted on them with white paint, and it is an easy matter to locate the correct size immediately. Bushings are tied to the pulley spokes and are also kept in small boxes according to their size.

East Berlin, Conn. H. S. RICH.

Rotors of Old-Style Induction Motors Welded by Oxy-Acetylene Torch

REPAIRS on the old-type induction motors, of which many thousands are still in service, are often regarded as only temporary. The rotor bars in these old motors are heavy conductors embedded in laminated cores and short circuited on the ends by means of brass, bronze or copper rings to form circuits for the current induced in the rotor winding. The bars, or conductors, are usually attached to the resisting rings with rivets, screws, bolts or solder. These connections frequently work loose under constant vibration or from expansion and contraction, due to heating and cooling, and thereby reduce the positiveness of the contact. Also particles

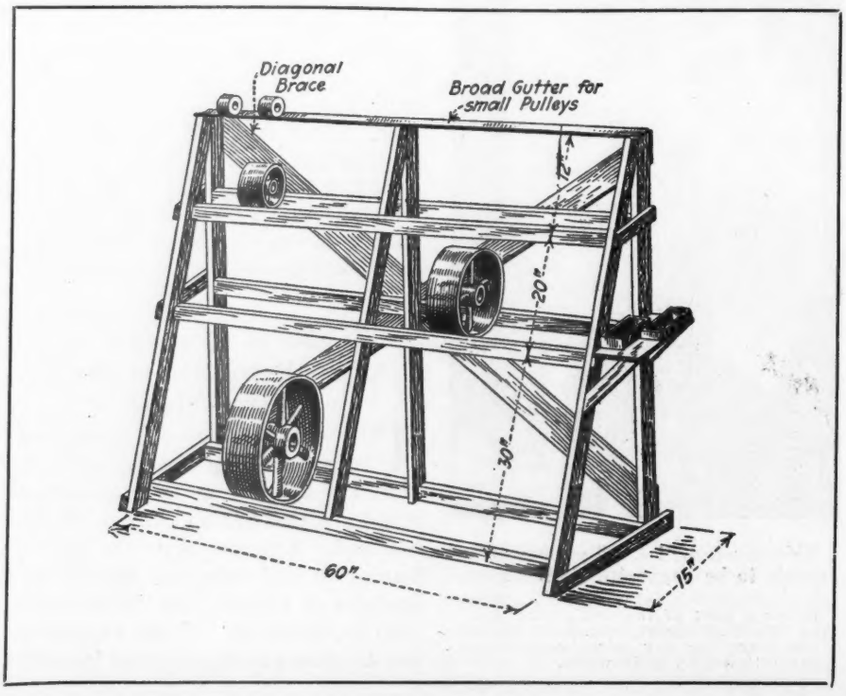


A rotor of an old-type induction motor reconditioned by welding instead of soldering.

of dust sift into the minute crevices, and in time may seriously impede the conduction of the current. Finally the contact areas become sufficiently reduced to cause overheating and formation of a scale that will finally destroy the contact altogether. Before this stage is reached, however, the motor will give trouble in starting, will overheat, and will drag or run at retarded speed.

The usual way of repairing a burned out or dragging motor is to remove the bars and rings of the rotor and replace them with new construction of the same kind. This virtually renews the motor, but it does not overcome the original fault, which was not so much one of design as it was an error in fabrication. A quicker and much more satisfactory mode of repair, according to reports received from El Paso, Tex., where more than $50,000 worth of old motors have been reclaimed for the Southwestern Portland Cement Co. in the past eighteen months, is to make permanent contacts with the welding torch. This can be done, it is claimed, at approximately the same cost as for the old way of reconditioning. The advantages of welding over the old method lies in the shorter time required and in the greater permanence and serviceability of the motor.

Motors of 5, 10, 20, 50, 90 and 150 hp. have been reclaimed at this plant in the following manner: The rotors are removed from the stators and placed in a lathe so the bar ends can be bevelled to an angle of 45 deg., starting from the ring surface. The metal removed is then replaced by a ring of the best Tobin bronze welding rod, properly fluxed and welded with the oxy-acetylene blowpipe. The bars are bonded to the rings, and the weld run back between the bars a half or three quarters of an inch (according to the size of the bars, the rings and the rotor as a whole) to insure sufficient conduction area at the joints. To facilitate welding, the rotor should be placed so it can be revolved on "horses" or trestles, the operator being stationed at one side, where he can weld and turn the rotor as his work progresses. Owing to the char-



Rack for pulleys allows the size wanted to be located immediately.

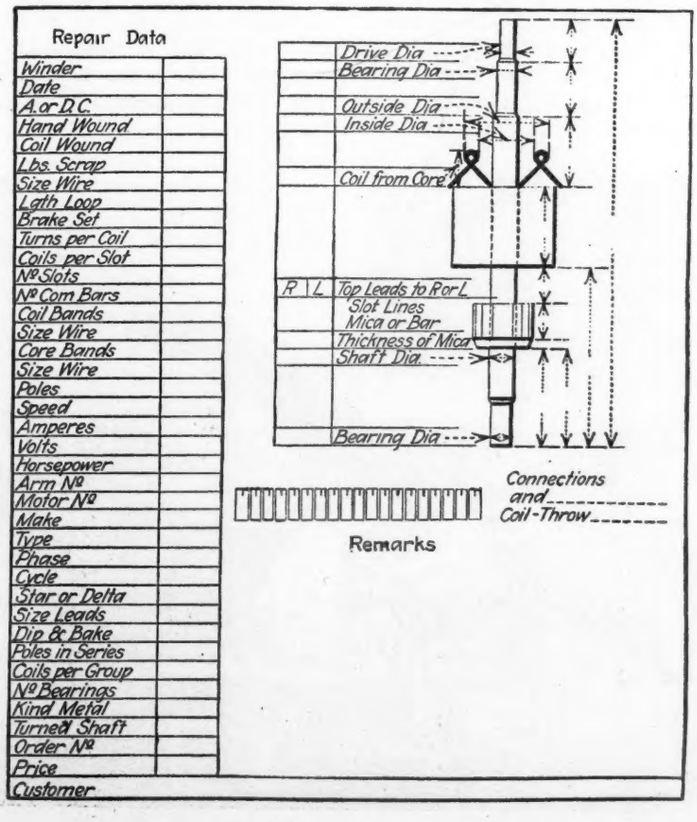
acter of the metals to be bonded, it is necessary to use a "hot flame," that is a large-size welding tip. When the welding is completed and the work has had time to cool, the rotor is again placed in the lathe and finished. If the work is carefully and properly performed no trouble should be encountered and the operation of the rotor is greatly improved.

The first motor reclaimed, one of 90 hp., for the Southwestern Portland Cement Co., ran continuously for six weeks without stopping, with no signs of wear.

Data Sheet for Armature Winding and Repair Information

FOR recording complete data on motors being repaired in the shops of the Edward Ford Plate Glass Company, Rockford, Ohio, the form shown here is used. In the left-hand corner of this 11-in. by 11½-in. special repair data sheet is a column for recording the nameplate data of the motor, information on the type of winding and other parts of the motor, including the bearings. In the right-hand side of the sheet is a diagram opposite which is a column where the dimensions of the machine, including those of the bearings, the coils, the commutator, etc., may be placed. In this column may also be recorded the shape of the coils as well as their throw. In the lower right-hand corner of the sheet is a large space in which are placed remarks.

Record sheet for motor which is being repaired.



Increasing Air Gap Removed Starting Trouble With Motor-Generator Set

OCCASIONALLY trouble which is new in the experience of the repair man develops in electrical equipment. Such a case came up some time ago in connection with the starting performance of a standard make 112-hp., three-phase, 25-cycle, 440-volt, 75-kw. direct current motor-generator unit.

In the starting position, with the half-voltage tap on the compensator, the motor took about 600 amperes or 5 times full load current, barely turned over and chattered violently. The unit was of the two-bearing pedestal type with the base firmly grouted in. The alignment of the stator frame was adjusted by means of shims to secure an even air gap when at rest. When the unit was started the rotor apparently attempted to cling to the top of the stator and rubbed the stator iron.

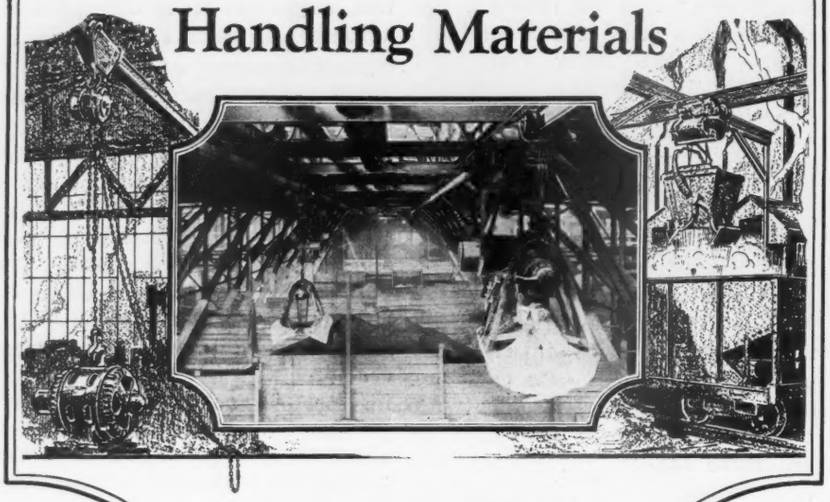
It was thought that the current distribution in the winding, which was a two-path star connection, might not be equalized, but an ammeter in each circuit and an equalizing connection between pole-phase groups eliminated this possibility. Evidently it was essential to eliminate all possible vertical movement of the rotating element in the bearings, prevent any shifting of the stator frame and to investigate possible vibration of the shaft of the unit. After concluding this investigation and slightly increasing the air gap at the top of the stator as compared with the bottom, the starting performance was slightly improved. However, the machine would not come up to speed on starting and took about four times full load current on the starting position. Upon consulting the manufacturers, it was found that we could increase the air gap .012 in. without seriously affecting the performance of the motor. A cut of .012 in. was taken off the rotor iron in a lathe. When the machine was reassembled, it quickly came up to speed on the lowest tap of the compensator with a maximum starting current under two times full load current and now shows normal performance as to heating at full load.

While the rotating element was out of the machine some of the rotor bars were found to have loosened up due to the strain imposed by the severe starting conditions. These bars were silver-soldered before the rotor was replaced. It is practically useless to use ordinary solder on rotors, as any severe overload will cause the rotor bars to heat and throw out ordinary solder. It is comparatively easy to silver-solder rotor bars if the copper section is large enough to prevent melting the copper under the oxy-acetylene flame, even when extremely careful.

There is one point to observe and that is to have the copper absolutely clean. In this case the cleaning was accomplished by suspending the rotor by means of a crane over a small tank of chemical cleaning compound which was kept boiling by means of a gas heater. The rotor was revolved in this cleaner and all dirt, grease and foreign matter was quickly removed, after which the rotor was silver-soldered, using an oxy-acetylene torch, with borax as a flux.

East St. Louis, Ill. J. E. HOUSLEY.

Handling Materials



Better ways to transport and handle raw and finished parts in and around the works will be discussed in this section.

How One Industrial Plant Saves Money by Handling Coal With a Portable Loader and an Industrial Truck

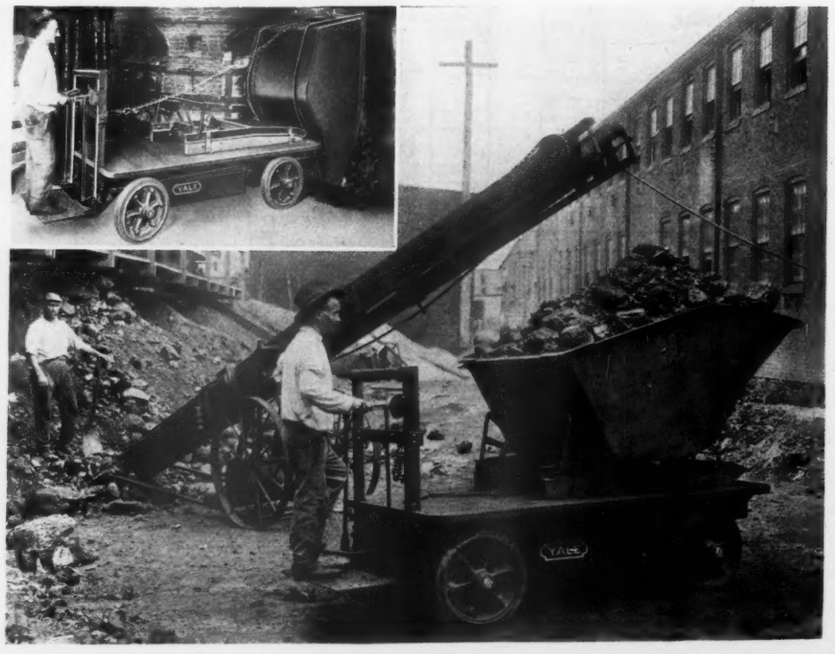
WHEREVER men are handling material in small quantities over a considerable distance by hand truck or wheelbarrow it always pays to ascertain whether some mechanical or electrical equipment can be used so that larger loads and fewer trips may be made. Formerly at the Trenton, N. J., plant of the Star Porcelain Company all the coal was handled from storage to the kilns, a distance of approximately 450 ft. for the round trip, by wheelbarrows. It required about a ton of coal daily for each kiln and kept three men busy all the time.

It was realized that the amount of coal handled was too small when compared with the time required for a man to make the round trip. The obvious solution was the use of power-driven equipment which would enable him to transport, say, a ton of coal in the same time that it took to push a wheelbarrow containing about 250 lbs., thus doing in one trip what ordinarily would require eight round trips. At only five minutes a round trip, this would mean a man saving of thirty-five minutes on each ton handled, assuming that the loading time remained the same, irrespective of whether the coal was loaded into wheelbarrows or a truck.

A Yale & Towne platform storage battery truck with a dump body, as shown in the accompanying illustration, was installed to do the hauling. This dump body holds over a ton of coal at a load and can charge a furnace at one trip. The round trip of 450 ft. is made in four minutes. Instead of loading the coal by hand, the truck is loaded by a portable scoop conveyor as illustrated. The coal is dumped from the gondolas, which run into the yard on a trestlework, a portion of which is shown at the left in the illustration. The portable scoop conveyor is bucked up against the pile and the coal pushed into it by one man with a shovel. It requires only a minute or two to load the special dump body. At the kilns the load is dumped by a simple tripping device. With this equipment two men are able to coal all the kilns in two hours, as compared with three men all day with wheelbarrows.

During the remainder of the day the dump body is removed—it can be taken off or put on in five minutes, as it is held in place by four bolts—and the truck is used for general hauling about the plant as well as for trucking the finished product from the kiln shed to the wareroom.

The time of three men all day, 300 days a year, at $3 a day, costs $2,700. Two men, two hours (¼ day), at $3 a day for 300 days, amounts to $450. This makes a saving of $2,250 a year in the handling of coal alone, which can be applied toward the cost of the equipment. Because the other work handled is of such a miscellaneous nature, it is difficult to get the actual saving, but the total is considerably above the cost of the equipment. The truck and special dump body were supplied by the Yale & Towne Manufacturing Company, Stamford, Conn.



Saving $2,250 a year in the labor cost of coaling porcelain kilns.

When this was done by three men with wheelbarrows it took all day. Now with this portable scoop conveyor and industrial truck with dump body two men are able to do the coaling in two hours. The largest proportion of the saving lies in making one four-minute trip with a ton load instead of a number of five or six-minute trips with small loads. The dump body is removed in five minutes and the truck used for other hauling for the rest of the day.

Three Barrels a Minute from the Basement to the Box Car by Conveyors

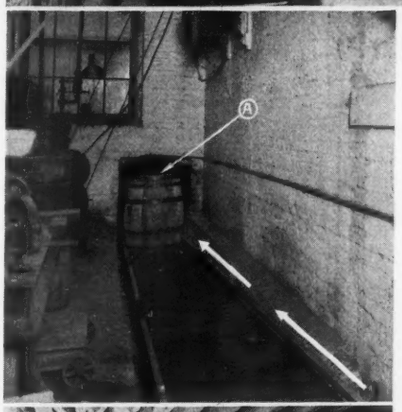
WHEN the Chicago plant of the D. W. Ryan Cooperage Company was built it was designed to receive barrel staves and heads at the railroad siding along the rear of the plant and ship the barrels out at the front or street side of the plant, as practically all the output was delivered by wagon or truck to Chicago customers. As the business grew, carload deliveries had to be trucked to a team-track freight yard because, due to the construction of the buildings, it was not possible to get the finished barrels or kegs back through the plant to load on the freight cars.

Finally a passageway was cut through the walls and the conveyor system shown in the three accompanying illustrations installed. This conveyor takes the barrels from the basement, where they are finished, to the cars, a distance of over 200 ft. The total elevation is about 15 ft., but the building is so constructed that it is necessary to have three separate elevating sections with roller-gravity sections in between and at one place to go almost as low as where they started.

The finished barrels or kegs are stored in the basement until a carload is ready for shipment, as shown at the right in Fig. 1, the lower of the three accompanying illustrations. A section of roller conveyor extends out toward the center of this room and carries the barrels by gravity to the elevating section, or power "spiked" pallet conveyor, shown in the foreground of Fig. 1, which elevates and carries them through the opening cut in the wall and then raises them high enough to go by gravity through the tunnel *"A"* shown in Fig. 2. This same opening can be seen in the distance in Fig. 1, and was depressed so as to go under a passageway between two buildings.

This roller section discharges onto another power "spiked" pallet section shown in Fig. 3, at the top of the page. This section of the conveyor may be set to discharge in either of two ways: (1) the barrels may go straight out through the door at *"B"* directly into a car on a short portable section of roller conveyor; or, (2) the barrels may be "switched" off at right angles as shown by the arrows on the wall, onto a gravity and elevating section which discharges through the door at *"C"* on portable sections of roller conveyor extending along the shipping platform.

With this conveyor system two men—one in the basement and one in the car—can easily load a car of 185 barrels in about an hour. Formerly, it required three men and a team all day to haul a carload of barrels to the team track. The conveyor system was installed by the Mathews Gravity Carrier Company, Ellwood City, Pa.



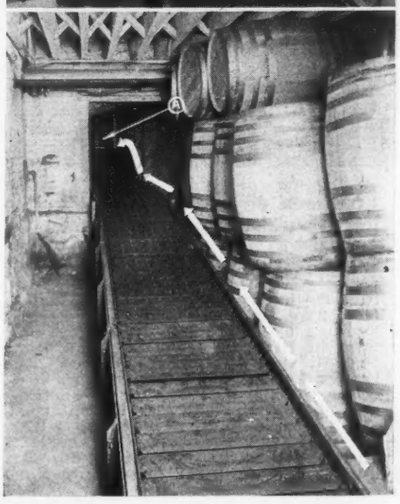


Fig. 1. Barrels are stored in the basement as finished until ready to load into a car.

A section of roller gravity conveyor (not shown here) brings the barrels to this "spiked" pallet power elevating section shown at the lower left. The tunnel marked "A" is the same as shown in Fig. 2.

Fig. 2. The barrels have to dip down through a tunnel under a passageway between two buildings.

Roller gravity conveyors carry the empty barrels from the power section shown in Fig. 1, through this tunnel to the elevating section shown in Fig. 3 at the top of the page.

Fig. 3. The barrels are loaded on the cars through the door "B" or from "C," which opens onto the loading platform.

When the basement is filled and no cars are available, this shed may be used for storage. Ordinarily, however, the barrels go directly to the cars. Portable sections of roller conveyors carry the barrels inside the cars so that one man can handle them.

Tier-Lift Truck Facilitates Loading of Cars From the Ground

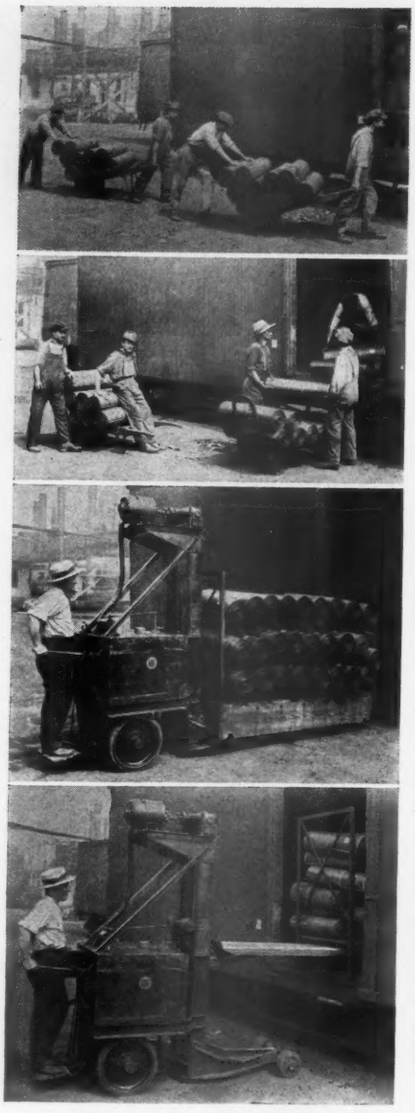
LOADING cars, particularly when they must be loaded from the ground without a loading platform, is usually a time-consuming and expensive operation. The work may be speeded up and done at lower cost, however, through finding a better method as was the case at the Shadyside, N. J., plant of the Barrett Company. Here rolls of tarred paper had been hauled on two-wheeled warehouse trucks, as shown in the two upper illustrations on the next page. Each truck required two men—one to push and the other to pull—and hauled only 10 rolls at a trip. The trucker and his helper would then pile the rolls into the car where men inside had to stoop over and lift them from the floor, which

made it more fatiguing and so harder on the men. Also, if a truck reached the car before the preceding one was unloaded, the two men had to idle about until they could get their turn, as shown in the second illustration of the series.

When a Lakewood tier-lift truck was put at this work, the load per trip was increased from 10 rolls to 50 by using the special skids shown in the third illustration. One man and the truck does all the traveling back and forth faster than could the men with their hand trucks and makes only one-fifth the trips, which is a big saving in time. It takes only a short time to deposit the loaded skid, remove the empty skid from the car, set it to one side, pick up the empty skid and return it to the car, back off, and again pick up an empty skid to return it to the warehouse for another load. Two men at the warehouse load skids, two in the car unload them, so that with the trucker, a five-man gang does in half the time the work formerly requiring nine men. Also the men in the car do not have to stoop so low to lift the rolls—over half the skid may be unloaded without stooping—which makes the work easier on them.

The tier-lift, either with skids or with the load carried directly on the platform of the truck, is also used for loading motor trucks. Many other materials, such as boxes, crates, barrels, and so on, are loaded on cars or trucks with this truck in addition to rolls of paper. The tier-lift truck and skid can also be used in unloading by reversing the process. Altogether the labor costs of handling materials have been reduced 30 per cent to 40 per cent at this plant, through the new plan.

Considerable advantage arises from the use of a tier-lift truck in loading or unloading motor trucks, especially from or to yard storage. Barrels, which are often stored outside, were, under the old method, rolled up to or down from the motor truck on long skids. With the truck a wooden platform is elevated to the level of the motor truck and the barrel rolled on or off. It is a comparatively easy task to take the barrel off the platform compared with letting it down from the truck. Concrete paving in the loading yard not only makes handling easier, but also speeds it up through enabling larger loads to be handled. It also increases the life of the truck.



Five men do nine men's work in less than half the time formerly required.

With a tier-lift truck installed to do this work only one man makes the trip back and forth, but he carries five times the load formerly handled by two men. Also the two men in the car to unload and the two in the warehouse to load up have practically no time to loaf, because the truck is constantly on the go between the car and warehouse, and the men have to keep up with it. The work, however, is easier on the men in the car as they do not have to stoop so far to pick up the rolls of paper.

The Lakewood Engineering Company, Cleveland, Ohio, make this tier-lift truck in three sizes with maximum platform lifting heights of 42, 60 and 76 inches. Power for both travel and elevation is furnished by a storage battery. The platform is elevated with a 2-ton load at a speed of 1 ft. in 18 sec. by two screws driven by a separate motor. With average operation the electrical energy used costs about 40 cents per day.

Red Lights in Aisles Call Industrial Truck Operators When Truck Is Needed

WHEN a plant installs electric storage battery trucks or delegates a special department to look after all material handling, even by hand trucks, it is essential that some system be used for notifying the "move" men that a load of material is ready in order that they may not waste time by stopping the operators to ask about the work or where it is to be taken. Various methods are used for this. For example, in one plant red semaphores are attached to building columns and when "set," extended out into the aisle to indicate that a trucker is wanted. In other plants, cards are set up similar to those used to attract the expressmen to the shipping room door. In either case it is somewhat difficult for the "move" men to see these signals at a distance, especially in shops with shafting and belts or where localized lighting is used instead of general lighting.

A signal system which cannot be overlooked, as installed by one company, consists of red bulbs suspended from the ceiling along the main aisle at each cross aisle. If there were any danger of getting red bulbs confused with the exit signals, any other color could be used as well. Whenever work is ready to be picked up, the foreman or inspector turns on the signal lamp. The trucker on his regular scheduled round does not have to stop and interfere with the men to inquire about work ready to be moved. He stops only on signal and can tell which job is ready to be moved and where it is to go by a conspicuous "move" order on it. The prominence of the signal enables the truckers to pick out the places where they are wanted without any delay. A large amount of time is wasted in the average shop by the "move" men through their wantering about looking for work to move and its destination. They also waste the time of others.

It was not necessary to run a separate circuit for this signal system as the lights are tapped into the regular lighting circuit. In this plant most of these signals are controlled by snap switches placed on convenient columns; a few signals, however, where no columns are convenient, use pull-chain ceiling switches.

Some Pointers On Bearings

(*Continued from page 270*)

drilled, one is placed directly in the bottom or lowest point of the bearing bore and the other two a short distance up the curvature.

Tracing the oil in its flow through the sleeve bearing, starting at the edge of the oil-ring slot it flows down the pitched oilways toward the ends of the bearing sleeve. The surface of the oil stream is wiped off by the outer surface of the shaft in its rotation and forced or spread over the inner portion of the bearing to the drain groove cut in each end of the inner bore of the sleeve. Here it collects and flows by gravity downward in this groove until it reaches one of the holes bored through the sleeve, runs through this hole and off the outer surface of the sleeve back to the oil well through which the oil ring is rotating. The oil which flows through the pitched oilways cut in the bearing lining, but is not wiped over the surface of the lining, goes on until it reaches the draining groove cut in the end of the lining, thence to the nearest outlet hole and back to the oil well. By this uninterrupted oilway the oil flows through the various paths (usually four), thereby allowing any dust or grit that may drop into the bearing to be carried readily through the oilways of the bearing, without being sucked or wiped from these oilways and pressed into the softer bearing lining by the rotation of the shaft. Oilways such as these are intended for oil-lubricated bearings.

Table 1.—Data Taken During Test on New Bearing Alloy

Time	Room Temp.	Front Bearing	Pinion Bearing	Load Watts	Revolutions Per Min.
9:45	63 Deg. F.	56 Deg. F.	57 Deg. F.	0	.....
10:45	63 Deg. F.	56 Deg. F.	57 Deg. F.	0	.....
11:00	64 Deg. F.	85 Deg. F.	175 Deg. F.	Full	.....
11:15	63 Deg. F.	95 Deg. F.	220 Deg. F.	Full	1130
11:30	63 Deg. F.	99 Deg. F.	250 Deg. F.	Full	1130
11:45	64 Deg. F.	130 Deg. F.	232 Deg. F.	Full	1130
12:00	64 Deg. F.	143 Deg. F.	230 Deg. F.	Full	1130
12:15	63 Deg. F.	172 Deg. F.	237 Deg. F.	Full	1140
12:30	65 Deg. F.	250 Deg. F.	230 Deg. F.	4000	1020
12:45	65 Deg. F.	235 Deg. F.	232 Deg. F.	Full	.....
1:00	66 Deg. F.	211 Deg. F.	240 Deg. F.	3300	1050
1:15	67 Deg. F.	208 Deg. F.	250 Deg. F.	Full	1130
1:30	67 Deg. F.	198 Deg. F.	240 Deg. F.	Full	1130
1:45	67 Deg. F.	192 Deg. F.	240 Deg. F.	3300	1050
2:00	67 Deg. F.	188 Deg. F.	244 Deg. F.	3300	.....
2:15	67 Deg. F.	209 Deg. F.	260 Deg. F.	Full	.....
2:30	68 Deg. F.	187 Deg. F.	234 Deg. F.	Full	.....
2:45	68 Deg. F.	194 Deg. F.	245 Deg. F.	3900	1030
3:00	68 Deg. F.	207 Deg. F.	250 Deg. F.	Full	.....
3:15	68 Deg. F.	206 Deg. F.	248 Deg. F.	2800	.....
3:30	68 Deg. F.	211 Deg. F.	262 Deg. F.	3000	.....
3:45	68 Deg. F.	202 Deg. F.	245 Deg. F.	Full	.....
4:00	68 Deg. F.	207 Deg. F.	242 Deg. F.	3300	.....
4:15	68 Deg. F.	208 Deg. F.	256 Deg. F.	3800	1040
4:30	68 Deg. F.	203 Deg. F.	240 Deg. F.	3600	.....
4:45	68 Deg. F.	205 Deg. F.	240 Deg. F.	3000	.....
5:00	68 Deg. F.	199 Deg. F.	245 Deg. F.	2800	.....

Table 2.—Test of Ackermite Bearing Metal

Time	Temp. Deg. F.	Ackermite No Oil Deg. F.	Cast Brass Oil Used Deg. F.
9:15	66	.....	.....
9:30	67	57	57
9:45	68	98	66
10:00	69	140	75
10:15	69	223	81
10:30	70	225	88
10:45	71	253	131
11:00	71.5	225	143
11:15	72	260	153
11:30	72	227	154
11:45	73	226	143
12:00N	73.5	181	135
12:15	73	160	127
12:30	72.5	152	122
12:45	73	150	119
1:00	75	147	117
1:15	76	150	117
1:30	76	165	122
1:45	77	167	131
2:00	77	298	141
2:15	78	326	153
2:30	79	317	155
2:45	80	267	154
3:00	80	280	179
3:15	82	293	235
3:30	.....	.....	.....

In the course of my work I frequently run tests on new bearing metals, and Fig. 10 is an Esterline chart taken on a 3-hp., three-phase, 60-cycle squirrel-cage induction motor of the back-geared type during a heat and wear-out test of a composition bearing. I understand that the alloy composing this bearing contains 70 per cent of lead and 30 per cent of copper. These bearings operated nicely for four and three-

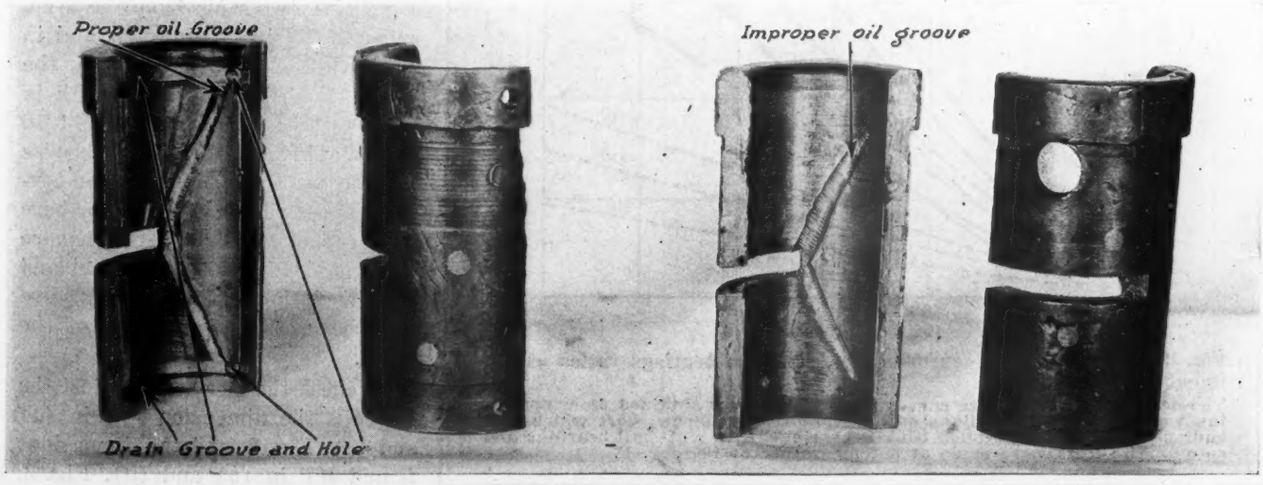


Fig. 11—Two ways in which oil grooves may be cut.

In the bearing at the left the oil grooves slope down from the oil-ring slot to draining grooves cut in each end of the babbitt lining. Holes drilled in the lower portion of the draining groove allow the oil passing through the bearing to flow back into the oil well. The usual method of cutting oilways is shown on the bearings at the right.

quarters hours without any lubrication whatever before they finally wore down sufficiently to cause rubbing of the rotor and stator. At the completion of the test it was found, however, that the rotor required a new shaft by reason of the wear and near-freezing effect of this alloy upon the shaft. These bearings also had a tendency to swell at portions not held firmly compressed by the housing. Table 1 shows data taken during the test.

At the right in Fig. 10 is a chart taken for the same motor when Ackermite metal was used for the pinion end bearing, while the front end bearing was made of cast brass, using an oil ring and oil lubrication. Table 2 gives the data taken during this test. Ackermite is also essentially an alloy of lead and copper, although I do not know the percentage. It differs, however, from the other lead-copper alloy in that when it is remelted a number of times no segregation of lead can be noticed at the bottom while with the first alloy segregation was apparent upon the second and third remelting. The two ends of a 6-in. circular rod 1 in. in diameter also showed a difference when subjected to hardness tests.

Fig. 12—The life of the bearings in this motor is only two or three months.

The tumbling barrel which is driven by this motor produces a large amount of iron oxide dust which is sufficiently abrasive to cut the bearings rapidly. They are inspected several times a day and when they heat unduly or show other abnormal behavior are immediately replaced, in order to avoid the possibility of serious injury to the motor.

When examined after the Ackermite bearing had worn out completely, the shaft was found to be highly polished, with no evidence of scoring, although it had been blued by the high temperature.

A very large amount of work has been done on bearings and in Fig. 13 there is given the results of some tests conducted by Prof. Carl C. Thomas of the University of Wisconsin on the power consumed by friction in babbitt, roller and ball bearings at various loads and speeds.

The relative amounts of power consumed in friction by the different kinds of bearings, as determined by Prof. Thomas, are as follows: With a shaft speed of 100 ft. per min. and at a temperature of 77 deg. F., babbitt bearings consumed three times, and roller bearings consumed 2.2 times as much power as ball bearings. At 100 deg. F., with the same speed, the ratio became babbitt bearing 3.6, roller bearing 2.5, ball bearing 1.0.

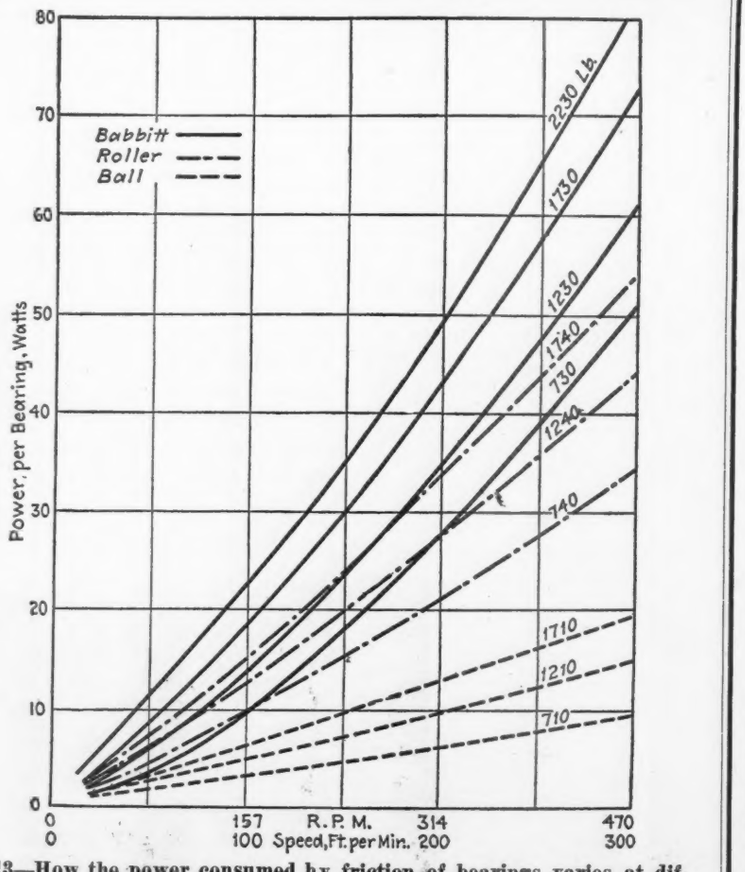


Fig. 13—How the power consumed by friction of bearings varies at different loads and speeds.

The data from which these curves were plotted was obtained from recording watt-hour meter readings of a motor driving a long shaft which was equipped first with ring-oiled babbitt bearings, then with ball bearings and so on. The tests were made at a temperature of 100 deg. F.

Diagrams for Coil Winders

(*Continued from page* 288)

At the bottom of the card is a notation, "Wire Space," which tells what size to make the slots on shuttles and the space in the jaws of the pulling machine. In figuring this size, the wire-space table (Table III) will save time. This table shows the width of slot necessary for any number of double-cotton-covered round wires up to twelve. For instance, with a coil of No. 8 gage wire, two wide by three deep, under No. 8 in the top row and in line with 2 of the first column is the figure 19/64, which is the width in inches of the coil. Similarly 11/16 in. is the height. Table IV likewise may be used for double-cotton-covered copper ribbon, Table V for bare strap copper and Table VI for square and round with cotton, enamel and silk insulation. These tables give also the cross-sectional area of the wires.

To check the new coils against the old coils the dimension *F-F* in (*a*) and (*c*), Fig. 3, and the dimensions *B* and *HT* in (*b*) and (*d*), Fig. 3,

are used. *F* is the distance between the center lines of the shuttle pins and of the coil when pulled to shape. This is a check on the coil length, and the total inside length of the coil is *E*+2*F*. *B* is a check on the angle *D* or the coil pitch. This is measured as shown in (*b*) and (*d*), Fig. 3. *HT* is the height of the coil at the diamond point from the bench where it lies as in (*b*) Fig. 3.

Further details on the winding procedure for the coils discussed here will be published in another issue of ELECTRICAL REVIEW AND INDUSTRIAL ENGINEER.

Motor Service Panels With Standardized Equipment.

(*Continued from page* 274.)

A panel for a synchronous motor and exciter is shown in *A* of Fig. 3 and at the right-hand side of the illustration on page 271. On motor-generators when the synchronous motor is excited from the generator, the exciter rheostat and voltmeter are omitted from the panel. Some motor builders do not furnish a field switch but insert a protective resistor with a short-circuiting fuse in the motor-field circuit. If this scheme is used, the field switch is omitted and the protective resistor is mounted in place of the field-discharge resistor. The panel described may be used to control a squirrel-cage induction motor by omitting the rheostats and mounting the ammeter and relays as shown at *D* and *E* in Fig. 4.

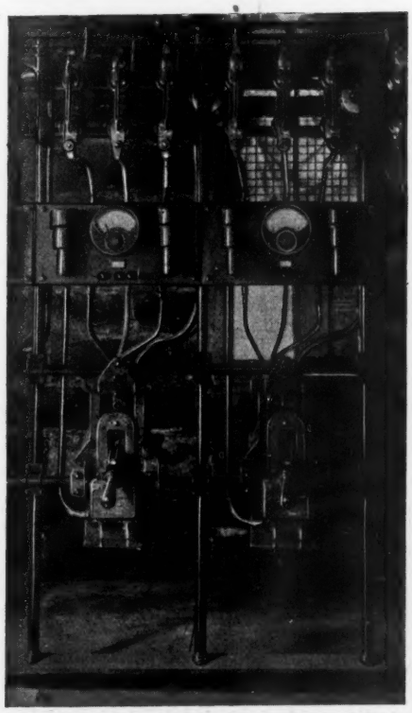


Fig. 2—Two standard feeder panels for an industrial substation. See E in Fig 4 and D in Fig. 1.

Another good type of panel for controlling squirrel-cage motors is shown in *B* of Fig. 3. The wiring diagram is shown in *B* of Fig. 1. In this case standard series overload relays are omitted from the self-contained compensator. The current transformers are wired in the running leads and operate relays on the panels which function with the oil-circuit-breaker trip coil. This arrangement prevents the compensator opening except on low voltage, for which purpose the compensator is equipped with an undervoltage release attachment. Overload and short-circuit troubles on the motor are handled by the oil circuit breakers.

Materials Needed for Different Feeder and Motor Panels

The letters in columns one and seven refer to the items designated by the corresponding letters in the Master List, on page 273, giving a description of materials needed for different switchboard panels. The numbers in this table indicate how many items of each kind are required.

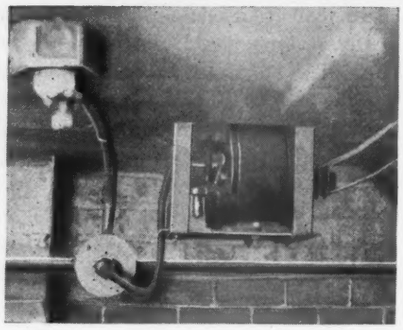
Designating Mark of Part—See Master List	NUMBER OF PARTS REQUIRED					Designating Mark of Part—See Master List	NUMBER OF PARTS REQUIRED				
	For Slip-ring Motor, D in Fig. 4	For Squirrel-cage Motor, B in Fig. 3	For Synchronous Motor, A in Fig. 3	For Incoming Line, C in Fig. 4	For Feeder, E in Fig. 4		For Slip-ring Motor, D in Fig. 4	For Squirrel-cage Motor, B in Fig. 3	For Synchronous Motor, A in Fig. 3	For Incoming Line, C in Fig. 4	For Feeder, E in Fig. 4
A	1	1	2	2	2	W	2	2	2	2	2
B	1	1				X	3	3	3	3	3
C	2	4				Y	1	1		1	1
D	2	2	4	4	4	Z			1		
E	1					AA	1				
F	1					BB		1			
G			2	2	2	CC				1	
H			2			DD	1	1			1
I	4	4	8	8	8	EE			1		
J	5	6	6	4	4	FF	1		2	2	2
K	3	4	4	2	2	GG			3		
L	8	10	6	7	6	HH			1		
M			1	1		II			1		
N	2	2	2	2	2	JJ			1		
O	3	2	17	6	2	KK			1		
P	10	12	12	8	8	LL			1		
Q	6					MM			1		
R	4	4	2	4	4	NN			1		
S	2	4	9			OO	1	1	1	1	1
T	4	4	14	4	4	PP			1	1	1
U	1	1		1	1	QQ				2	2
V	1	1	1	2							

Small Motors That Drive Machines

(*Continued from page* 293)

Brush springs on small motors are of compression and expansion types in coil form. The pressure on the brush varies with the length of the brush and consequently with the wear. The brush springs should not be used to conduct the current to the brushes, as this tends to heat and anneal the springs. Brushes on fractional horse-power motors should in most cases be of a 50-50 grade; that is, 50 per cent carbon and 50 per cent graphite. A very hard surface does not wear but cuts into the commutator, making it necessary to replace it in a short time. Graphite brushes are soft and in most cases last only a short time. By using a good grade of carbon brush, a smooth finish is put on the commutator and the tendency for either the brush or commutator to wear is very small. Where hard mica is used in the manufacture of a commutator the brushes are soon "chewed up," as the mica projects over the copper segments and cuts the brushes. Commutators in this condition can be kept running by sandpapering or by applying a commutator stone. To eliminate the wearing of brushes where hard mica or high mica is found, this should be undercut 1/32 in. below the copper, using a hacksaw blade the same width as the mica. Undercutting the mica on a commutator prolongs the life of the brushes, but unless the commutators are kept clean, so that the undercut sections do not accumulate carbon and oil, short circuits will result. Undercut commutators should be cleaned every month by running the end of a hacksaw blade, which has been ground for the purpose, between the segments. When a commutator has been worn to about 50 per cent of its original size, it will begin to spark considerably and wear out the brushes. This is usually because the brushes cover more segments of the commutator than they should. Replacing the commutator with a new one is the only remedy for such a condition.

Bearings play an important part in motor performance, as the accuracy of their construction determines the position of the armature with respect to field poles or the stator. Motor bearings are made of bronze, cast brass and bronze, babbitt and special white metal. They should be of a material that will wear more easily than the steel shaft of the armature. Motor bearings should maintain the air gap between armature and field poles or stator the same in all positions and they should also keep the armature core centered in the magnetic field path by limiting end play. If the end play lets the commutator pass from under the brushes and allows these to strike the armature leads, both leads and brushes will be broken.



Small motor mounted under work table.

This motor is mounted on a small bracket attached to the under side of the table and is fastened to the bracket by two bolts so that it can be easily removed. It is wired with a switch in addition to the separable plug attachment.

Motor bearings must be made to fit bearing housing so that no play exists between the two and should be self-aligning. In order to line bearings up properly and enable them to be adjusted in the housing, the outside of the bearing is turned to 0.002 to 0.005 in. under the size of the housing bore. Then the bearing can be placed in the housing without using much force. Starting ⅛ in. from each side of the center of the bearing, a light cut (1/32 in.) should be taken off the outside of the bearing. This reduces the outside section of the bearing by 1/32 in. with the exception of a ¼-in. shoulder having the proper fit for the bearing housing. This ¼-in. shoulder allows the bearing to line up in the housing, and also is wide enough for a set screw to hold the bearing in place and to be tapped for the oil cups. The bore of a bearing should be 0.002 in. larger than the shaft size, to allow for a film of oil. When there is too tight a fit in motor bearings they soon "freeze up," causing the armature to stop, with the resultant blowing of fuses or damage to windings.

MAKING BEARINGS FOR SMALL MOTORS

To make bearings for small motors, the stock should be chucked in a lathe, the end squared up and the outside of the stock turned 1/64 in. oversize. Then with a drill held in a drill chuck on the lathe, drill a hole about 1/32 in. undersize into the center of the bearing stock. The interior of the bearing is next bored to the proper size and the armature shaft is tried for fit. The outside of the bearing is next turned to the size of the housing and the end plate tried on. Much time can be wasted in the use of micrometers and accurate instruments on small armatures and motor end plates. Bearings can be made to fit directly, as the parts can all be handled easily. Another and simpler way to make fractional horse-power bearings involves the drilling of stock in the lathe with a drill 1/64 in. smaller than the shaft to be fitted. (*Continued on page* 314)

Some Points on The Maintenance of Small Motors

BEARINGS

Make sure that reservoirs are well supplied at all times with lubricant and that oil rings or other devices are functioning. Bearings should maintain a uniform air gap between armature and field poles or stator and should be frequently inspected to see that they allow only a small amount of end play.

COMMUTATOR

This is usually the weakest spot in an armature. Look there first for grounds and short or open circuits. Watch the brushes closely. Clean out under-cut commutators once a month.

FIELD AND ARMATURE

Dirt and dust should not be allowed to accumulate. If compressed air is used for cleaning a rubber hose should be employed instead of a metal nozzle. The coils should be painted with insulating varnish once a year. The load on the motor should be checked up when the motor is installed and whenever changes in location or load are made.

Trade Literature
you should know about

Dings Magnetic Separator Company, Milwaukee, Wis.—A series of bulletins describe the various types of magnetic separators and their numerous industrial uses, such as the extraction of "tramp iron," the separation of iron and steel from brass or other non-magnetic turnings and borings, the reclamation of iron from foundry refuse, as well as their application to several other industries.

The Lamson Company, Boston, Mass.—Literature is being distributed describing the various types of material handling equipment—pneumatic tube, power gravity conveyors and wire line-carriers—and their industrial applications. Numerous illustrations suggest the wide variety of material handling methods which may be applied to special lines of work.

Westinghouse Lamp Company, 165 Broadway, New York City—Bulletin E-103 gives the lighting code for factories and mills as prepared by the Illuminating Engineering Society.

Dayton-Rowd Company, Quincy, Ill.—Bulletin 248 describes and illustrates its type "CSV" multi-stage automatically balanced centrifugal pumps.

The Paul Maehler Company, 2210 West Lake Street, Chicago, Ill.—A recent catalog on "Maehler Ovens" describes the line of enameling, japanning, lacquering and core ovens for gas, electric, oil or steam heating. The construction, assembly, ventilation and circulation of the Maehler ovens and the fuels for industrial uses are discussed. Numerous ovens, particularly the conveyor and special types, are illustrated by halftones and diagrams.

Ingersoll-Rand Company, 11 Broadway, New York City.—Bulletin 10,004 describes the Price type "PO" horizontal, single-cylinder, single-acting, direct-injection oil engine.

The Van Dorn Electric Tool Company, Cleveland, Ohio—A new handy-duty, ball-bearing buffing machine, which has been recently added to the line of electrically driven machines put out by this company, is described in recent literature.

Westinghouse Lamp Company, 165 Broadway, New York City—"The Westinghouse Pocket Lighting Calculator," designed by the Illuminating Engineering Bureau of this company, has recently been published.

The Ingersoll-Rand Company, 11 Broadway, New York City—A 28-page booklet has been issued, describing the Price-Rathburn vertical, multi-cylinder, four stroke-cycle, stationary oil engines manufactured by the Rathburn-Jones Engineering Company exclusively for the Ingersoll-Rand Company.

Standard Conveyor Company, North St. Paul, Minn.—A booklet entitled "Gravity" describes the roller gravity and power conveyors, spiral chutes, inclined elevators and straight lift elevators put out by this company.

Link-Belt Company, Chicago, Ill.—Book No. 526 describes the line of portable loaders built by this company and illustrates their numerous uses for handling coal, sand, gravel and other loose materials.

The Yale & Towne Manufacturing Company, Stamford, Conn.—A group of bulletins issued by this company covers their full line of industrial storage battery tractors and trucks, load-bearing, elevating-platform, crane and special trucks and four-wheel knuckle-steer trailers for factory transportation.

Cutler-Hammer Manufacturing Company, Milwaukee, Wis.—A bulletin on "Battery Charging Equipment" describes and illustrates the principal types of charging apparatus. This will be worth having on file in any plant where industrial-truck or other battery charging is done.

Economy Engineering Company, 2655 West Van Buren Street, Chicago, Ill.—A recent bulletin describes "The Little Lifter," an economy portable elevator which may be operated from a lamp socket. Users of hand-operated machines up to 1,000 lbs. capacity may have motor and power hoisting mechanism installed easily. The 1/3-hp. motor can be supplied for any voltage and may be attached to any 660-watt lamp socket.

Garland Manufacturing Company, West Pittsburgh, Pa.—Recent bulletins call attention to "Galvaduct," a heavily galvanized conduit, and "Laricated," an enameled conduit.

Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.—Folder 4472, entitled "Shurvent Protection," explains the application and design of vented, removable fuses for the protection of low-voltage circuits up to 600 volts for both alternating and direct current. Every part of the Shurvent fuse is described and sketches are used to show how the renewal of both the ferrule and knife-blade types of fuses is accomplished. Various other subjects are also covered, such as style numbers, weights, prices and other tabulated data, and the conditions which must be met to obtain the Underwriters' approval.

The New Jersey Foundry & Machine Company, 90 West Street, New York City—Recent circulars describe the "Handiman," a new electric hoisting device which may be operated on both alternating and direct current.

Rochester Electric Products Corporation, Rochester, N. Y.—The first of a series of bulletins on "Little Motor Talks" has recently appeared. This deals particularly with the subject of brush mountings on small direct-current motors. This company will put anyone interested on the mailing list to receive the entire series as it is issued.

B. F. Sturtevant Company, Hyde Park, Boston, Mass.—Bulletin No. 288 contains an interesting paper by H. F. Hagen, research engineer, B. F. Sturtevant Company, on "Forced and Induced Draft with Mechanical Stokers," which was presented before the Stoker Manufacturers' Association. This takes up in detail investigations on the efficiencies of the various types of fan blades in supplying forced and induced draft. Another section of the paper calls attention to duct leakage—a troublesome loss in forced draft.

Kingsbury Machine Works, Philadelphia, Pa.—Catalog C, issued January 1, 1922, describes the Kingsbury thrust bearings, their construction and use. Numerous descriptions of installations of both horizontal and vertical bearings are included. Considerable space is given to power loss determinations, lubrication and radiation problems and instructions on the installation and operation of the Kingsbury thrust bearings.

Bussmann Manufacturing Company, St. Louis, Mo.—A recent booklet describes the new knife-blade type Buss removable fuse. This fuse is so constructed as to preclude faulty renewal and is approved in all sizes by the Underwriters' Laboratories.

Cowan Truck Company, Holyoke, Mass.—Electric storage battery tractor, elevating platform and load carrying industrial trucks for factory hailing are described in a series of folders. These are made in capacities up to 5,000 lbs. at from one to six or eight miles per hour, either forward or reverse.

The Cutter Company, Philadelphia, Pa.—A 16-page booklet describes the I. T. E. circuit breakers, both magnetically and motor operated for direct or alternating current lines, for generating stations.

Mutual Electric & Machine Company, Fort and Fourth streets, Detroit, Mich.—The 1922 Apparatus Division catalog describes and illustrates the various types of "Bull Dog" switchboards, knife switches, cutouts, panel boards and cabinets.

Gillis & Geoghegan, 537 West Broadway, New York City—A recent catalog describes telescopic hoists, either hand or motor operated, which are used to hoist materials from the basement to the sidewalk through an opening in the sidewalk. When not in use the hoist telescopes and the opening is closed with steel doors. These are made in 300 and 500 lbs. capacity and with a lifting speed of 30 ft. per min. for hand power ma-

chines and 60 ft. per min. for the power driven. This equipment is most commonly used for handling ashes, but many industrial plants use non-telescopic hoists as a derrick to handle material between floors.

Ilg Electric Ventilating Company, 2850 North Crawford Avenue, Chicago, Ill.—This company is distributing a small folder illustrating sixteen industrial ventilating problems, such as drying, removing fumes, dust, heat, and so on, and showing how they may be solved by various types of fan installations.

Allis-Chalmers Manufacturing Company, Milwaukee, Wis.—Bulletin No. 1123, "Small Steam Turbines," describes a line of small turbines suitable for driving exciters, small generators, and for use in many other places where auxiliary turbines are required.

Janette Manufacturing Company, 556-8 West Monroe Street, Chicago, Ill.—A recent broadside calls attention to the special-built Janette motors of 1/20 to ¼ hp. for direct or alternating current. The folder also gives a number of interesting views of the plant.

Russell Manufacturing Company, 814-18 Bath Avenue, Niagara Falls, N. Y.—Catalog No. 4, describes the "Standardized Electric Controller Finger" with reversible and renewable tips for all types of drum controllers, starters, and similar electrical control equipment. These fingers have a special detachable tip which may be reversed to give double wear or removed and replaced by a new one. Thus only the tip need be replaced instead of the whole finger.

Indiana Steel and Wire Company, Muncie, Ind.—Anyone who is interested may obtain a booklet entitled, "Double Galvanized Steel Strand and Iron Wire for Electrical Transmission and Distribution," which contains numerous tables and charts on "Effective Resistance, Internal Inductance, Internal Reactance and Line Loss," together with considerable other technical information.

Lapp Insulator Company, Inc., LeRoy, N. Y.—Bulletin No. 88 describes the Lapp "Overpotential" insulator test, a new feature in high voltage insulator production.

Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.—Catalog 5-A, Supplement No. 2, describes the Westinghouse line of insulating and soldering compounds which have been developed for use in the manufacture of Westinghouse equipment and are now being distributed for general manufacturing and repair purposes.

S. K. F. Industries, Inc., 465 Broadway, New York City—A booklet, "Ball Bearings for Electrical Machinery," describes and illustrates the various types of electrical equipment using ball bearings. Several curves and diagrams give the characteristics of ball and plain bearings.

Small Motors That Drive Machines

(*Continued from page* 312)

To finish, a straight reamer is then run through about three-fourths the length of the bearing. The reamer is then removed and the bearing trimmed to 1/32 in. longer than its finished length and pressed onto a straight reamer which cuts straight lines in the unreamed portion of the bearing. By using the reamer as a mandrel, the exterior of the bearing can be turned to size and the unfinished end faced off. The bearing is then removed from the mandrel by pushing the reamer straight out. Then the bearing is put into its housing on the motor, and the reamer can be turned through the bearing to finish the unreamed section. Drilling for an oil cup and set screw to maintain the position of the bearing and so limit the end play finishes the job.

When bearings are put into the end plates it is best to assemble the end plates with the armature and motor frame. Then adjust the bearings to get the proper end play for the armature before countersinking the hole in the bearing for the set screw. This eliminates the use of washers. Do not put the bearings in the end plates and try to adjust them by tightening up the end plate with the screws holding it to the motor frame.

Motor bearings on fractional horse-power motors are lubricated with dynamo oil, petroleum jelly or light greases contained in oil cups fastened to the bearings or housing, a felt wick serving to convey the lubricant to the bearing. The oil is absorbed by the wick and a small spring keeps it in constant contact with the armature shaft. Grease cups are placed on the top of the bearings and a copper rod riding on the armature shaft carries the grease down to the shaft. On oil-ring bearings a slot is cut into the top of the bearing by placing it in a lathe in an eccentric position and turning a slot of such width as to allow the oil ring to work freely. Oil rings should be watched to see that they do not become bent or otherwise damaged. An eccentric ring will cause the oil to be thrown from the motor bearings, or it may not travel with the armature shaft, and thus stop lubrication. Motor oil that is too light will run off the oil rings before reaching the shaft. After the oil has reached the shaft, the oil grooves carry it along the length of the bearing. These grooves should not be too large, as the corners will wear quickly and shorten the life of the bearing. Oil grooves 1/16 in. to ⅛ in. wide, depending on the size of the bearings, and 1/16 in. deep are sufficient. Oil grooves should run in a circular position, since straight grooves weaken the bearing surface.

The length of motor bearings is, on an average, two times the diameter of the shaft. Motor bearings on fractional horse-power motors have a life of six month to two years, depending on the work performed and the mechanical driving connection of the motor. A belt drive which is too tight will cause the motor bearing to wear in the direction of the pull. A loose belt or considerable slippage of a belt on a motor pulley results in the heating of the shaft and the evaporation of oil from the motor bearings. Gear drives on motors, if well loaded, will wear the bearings in the direction of the lift. Motor bearings can usually be worn down an average of 1/16 in. without affecting the efficiency of the motor or causing trouble. The mechanical connections by which machines are driven should always be inspected regularly and the effect they have on motor bearings should be studied.

Worn Armature Shafts Can Be Bushed to Proper Size with Steel Tubing

Armature shafts wear in time and can be brought back to standard size by turning down and then bushing up with a piece of standard steel tubing. Tubing can be purchased in the proper size to slip over the turned-down shaft and finished in a lathe to the standard diameter of the shaft. To make such a bushing, a piece of steel tubing is cut ¼ in. longer than the bearing section of the shaft and faced up in a lathe, allowing ⅛ in. extra length for driving onto the shaft with a hammer. The tubing is then heated to a cherry color, placed on the turned-down armature shaft and driven to the bearing shoulder of the shaft. After cooling the tubing in water, making a shrink fit, it can be turned down to the standard size.